The Sugar Beet and Beet Sugar

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THE HISTORY OF THE SUGAR BEET AND BEET SUGAR

Twelve years ago the beet sugar industry was unknown in Michigan. Last year there were in that state, roundly, 90,000 acres of land under beet cultivation, yielding 720,-000 tons of beets, which, cut in sixteen factories, turned out 90,000 tons of granulated sugar.

Prior to 1899 there was not a single sugar mill in Colorado. In 1908-09 beets were harvested in the mountain state from 126,842 acres, with a total yield of 1,-252,320 tons, which, worked up in 15 mills, gave 115,000 tons or 230,000,000 lbs. of granulated sugar.

Two decades ago there was practically no beet sugar industry in the United States. Now beets are grown on about 370,000 acres, yielding 3,600,000 tons of beets sliced in 63 factories, with a total annual output of 421,-000 tons of sugar.

One hundred and sixty-two years ago the world did not even dream of the presence of sugar in the beet. Now there are some 1,400 beet sugar factories the world over producing over 7,000,000 tons of sugar annually. Mankind knew only cane sugar produced in the tropics and shipped from there to other countries of the civilized world until the beet appeared on the world's stage and inaugurated a century lasting battle with the powerful cane.

It was the German chemist of the Berlin University, Andrew S. Marggraf who, in 1747, made the epochal discovery that the beet carries in its juice sugar of exactly the same properties as the sugar contained in the cane. Important as this discovery was, it did not yield any immediate consequences and its fate was that of other great discoveries: it was forgotten for a number of years by the outside world. The scientists, however, recognizing the great importance of the marvelous discovery, continued Marggraf's work, the main object in view being to find a practical method for the extraction of the sugar from beets. It required not less than half a century before Francis Karl Achard, the talented disciple of the discoverer, finally succeeded in inventing and elaborating a method of producing sugar from the beet on a large scale. So successful was Achard in his research work concerning both beet culture and sugar extraction from beets that he aroused wide popular interest, and rumors of his success reached even the king of Prussia, Frederick William III, with whose aid in 1799 the first beet sugar factory of the world was built on the Cunern estate, near Steinau, in Silesia. Pretty soon the erection of other sugar factories followed in Prussia as well as in other European countries. In Bohemia, for instance, sugar mills were in operation as early as 1802.

While factory building in France commenced only in 1811, it was nevertheless from the French dominion that the new industry on a large scale spread to other European countries. No less a personage than the great French emperor, Napoleon I, brought real life into the new industry. As a farsighted statesman, he recognized the great advantages connected with a future beet sugar industry that would produce at home all the sugar needed by his people. For this reason he at once, by a decree of 1812, appropriated 100,000 hectares, or 247,100 acres, exclusively for the cultivation of sugar beets and 1,000,000 francs for experiments in connection with beet raising and sugar extraction.

The interest of Napoleon was due to the continental blockade that excluded all products manufactured in England and her colonies from the European markets. As a consequence the price of cane sugar rose to an extraordinary height: it was more than 30 cents per pound in the period from 1807 to 1815. Under such circumstances the erection of beet sugar factories was a very profitable investment of capital and it is, therefore, not to be wondered at that in France, as early as 1812 some 40 factories were in operation, working up 98,813 tons of beets obtained from 16,758 acres, and yielding a total output of 3,300,000 lbs. of sugar. For the first time in the history beet sugar came to compete with the tropical product. From very modest beginnings in the first quarter of the nineteenth century the beet sugar industry grew to the enormous dimensions of to-day, crowding out cane sugar from the markets of the European continent and successfully competing with the tropical product in many other countries.

With the downfall of the first Napoleon and annulment of the continental blockade, cane sugar could be had on European markets at a very cheap price. This was a death blow for the new industry and a great number of the first beet sugar factories had to stop operation. It was inevitable, not only for the reason mentioned, but also on account of the poor methods used in both beet culture and sugar manufacture, making the cost of sugar production very high. While the first beet sugar factories in Germany were closed down and mostly converted into other industrial establishments, some sugar factories in France survived Napoleon's downfall—a fact due largely to essential improvements in the methods of sugar production which have been meanwhile introduced; as, for instance, juice extraction by means of hydraulic presses, filtration and purification with the aid of bone-black, application of steam for heating and boiling purposes instead of open fire, and so on. Pretty soon conditions in Germany changed in favor of the sugar beet. At the end of the twenties of the nineteenth century the price of all kinds of grain fell considerably. This compelled the farmers to take up the sugar beet again. The building of sugar factories started anew and the manufacture of beet sugar has increased ever since. A few statistical data will give us a good idea as to the gigantic progress made by the beet sugar industry, and show how the beet gradually gained superiority over cane in the fierce fight between the rival plants lasting already for a century. Thus, according to the bureau of statistics, the world's sugar crop derived from beets was:

In 1854-55	182,000 tons
In 1864-65	536,000 tons
In 1871-72	1,020,000 tons
In 1881-82	1,782,000 tons
In 1891-92	3,501,000 tons
In 1899-1900	5,510,000 tons

and at present the quantity of beet sugar produced per annum is over 7,000,000 tons. The ratio between beet and cane can be seen from the following table:

Year.	Total lbs. sugar.	% beet.	% cane.
1887	17,231,798,720	35.2	64.8
1890	18,636,976,160	43.0	57.0
1895	23,866,791,720	44.4	55.6
1900	24,274,564,160	50.8	49.2
1907	32,179,724,128	49.7	50.3

In connection with the historical data mentioned above, these figures are very interesting and instructive, indeed, as they show what the genius of men like Marggraf and Achard can create and what can be achieved through the efforts of two or three generations. Prior to 1747 mankind did not know even of the existence of sugar in the beet; prior to 1799 there was no beet sugar factory in the world; up to the middle of the nineteenth century the sugar obtained from the beets was quite insignificant in the world's sugar supply; now it plays a great if not predominant rôle on the globe's sugar markets, as not less than half of the saccharine matter needed by mankind is derived from beets. The time of the tropics being the one location producing the sweet stuff has passed away, nay, the center of gravity in the world's sugar supply has been removed from the tropics to the northern countries.

In the earliest development of the beet sugar industry it was believed that the beet was confined to certain regions. However, cultivated first in Silesia and Saxony, it gradually spread to other states of what is now known as the German empire, as well as to Austro-Hungary, France and Russia; and nowadays we can find it also in Sweden, Denmark, Belgium, Holland, Italy—in short, in all European countries with the exception of England and Norway.

Nor is Europe the only part of the world engaged in beet culture. A history of the extension of the beet would practically include all parts of the globe wherever civilized people live. The explanation for such wonderful expansion of interest in the beet is to be found on the one hand in the great adaptability of the beet to various climates and soils and on the other hand in the important economic advantages which come with the introduction of the beet sugar industry. In all countries where men have had long experience in beet culture, observations and results obtained have conclusively shown that it has proved to be a powerful factor in the regeneration of agriculture, as it necessitated doing away with the old, wasteful methods of cultivation and introduced scientific, intensive methods greatly improving the condition of the soil and its fertility, and hence benefiting also the crops rotating with the beet. As a consequence, land values increased wherever the sugar industry was established. It reclaimed much hitherto worthless land. It gave rise to many new industries, bringing healthful work and prosperity to the rural population. Pulp, molasses, the leaves, tops and broken ends of the beets, proved to be an excellent food for cattle and sheep; the resulting manure distributed on the fields returned the plant food removed by the beet crops. The refuse molasses has also brought into life a new alcohol industry. The advantages from growing sugar beets are so far-reaching and manifold that it would require too much space to go into the details of all the important consequences.

It should not be supposed, however, that the marvelous development of the beet sugar industry in France, Germany, Austro-Hungary, Russia, as well as in other European countries, took place always under favorable circumstances. On the contrary, a great many obstacles have been encountered; and it required much energy, knowledge, hard work and capital to overcome the difficulties. First of all, the farmers, having little experience in beet growing, furnished the factories with beets of very poor quality. This can evidently be seen from the fact that in 1872-73 the beets in France yielded 5.70 per cent sugar, while the output of sugar from the beets in the same country was 12.66 per cent on an average for the period between 1897-98 to 1906-07. The pretty low quality of the beets in Germany in the early development of the industry can be seen from the following figures:

In 1836-7 the sugar extraction from the beets was 5.55 per cent; in 1866-7 the sugar extraction from the beets was 7.93 per cent; while for the period from 1897-8 to 1906-7 it was 14.86 per cent.

Inexperience on the part of factory managers has been another drawback. Inferior methods in sugar making caused high losses, boiling of the purified sugar juices in open pans furnishing low grade sugar. In addition, struggling with cane sugar and sometimes unfavorable legislation hindered the growth of the industry. Nevertheless, it worked its way through all these difficulties to reach the present record.

Is it, then, to be wondered at, that the beet industry has found its triumphant way into this country? The history of its development in the United States is partly at least a repetition of what we have learned about it in Europe. At the infancy period of the industry in this country the failures were largely due to inexperience in beet raising, factory building and factory management, not to mention a score of other causes. The very first attempts to raise sugar beets in the United States date back to the thirties of the nineteenth century, a time when the European nations were struggling hard to establish the new beet industry. It was in 1830 that the first efforts to grow beets were made at Ensfield, near Philadelphia. In 1838 David L. Child made an attempt at Northampton, Mass., with the discouraging result that the beets yielded only 6 per cent of sugar. Later the Gennert brothers from Germany erected a sugar factory at Chatsworth, Ill., where they have been able to extract not more than 5½ per cent of sugar from the beets. They struggled for several years without success. The sugar mill was removed to several places and finally to California. The complete failure of all these enterprises was caused primarily and chiefly through lack of interest on the part of the farmers, who did not grow the necessary amount of beets, the quality of which, in addition, left very much to be desired. Besides this the choice of the locations was quite unfortunate, as neither soil nor climate was well adapted to beet culture.

The first successful sugar factory was built in 1870 at Alvarado, Cal. This factory, later reorganized and at present owned by the Alameda Sugar Company, is still in operation. Late in the seventies beet sugar factories were erected in the states of Maine, Massachusetts, New Jersey and Delaware—without any success. Again, the reason why the efforts to establish the beet sugar industry in those states failed is to be found mainly in the inexperience of the farmers to raise good beets and in sufficient quantity for the factories; further, in careless methods used in the mills by inexpert factory superintendents, in the small capacity of the sugar plants, making the production of sugar too expensive; and last but not least, in lack of capital. All the failures, bitter and costly as they were, furnished knowledge and were, consequently, material for the final success. They taught the farmers and factory managers how to avoid mistakes in the future.

By and by the systematic investigations made by the Department of Agriculture, the numerous publications in which Dr. Wiley, the present chief of the Bureau of Chemistry, laid down the results of his investigations in connection with the sugar beet, many experiments conducted in agricultural colleges and experiment stations (experiments that have demonstrated the conditions of soil and climate in many states to be favorable to beet culture)—all combined to arouse popular interest throughout the United States.

GRADUAL GROWTH OF THE INDUSTRY.

At the beginning of the nineties a great impetus was given to the sugar industry by the Oxnard brothers, men of remarkable success and considerable experience in the sugar business. They made a special trip to Europe for the express purpose of studying the beet sugar question, and they returned home with the strong conviction of great possibilities for the beet industry in this country. Energetic and practical as they were, they soon converted their belief in the beet industry into a fact by building a sugar mill in 1890 at Grand Island, Neb. In the following year they established two more sugar factories, one at Chino, Cal., and another at Norfolk, Neb. From that time the beet sugar industry awoke to genuine life and is now growing slowly but surely. Thus from half a dozen factories in 1892 with a total output of 13,000 tons of sugar, we see their number increased in 1902 already to 41 factories slicing 1,895,812 tons beets raised on 216,400 acres, with a total annual yield of 218,406 tons of sugar, a yield that was doubled in the last season (1908-9), when we find in operation 63 factories cutting, according to a preliminary estimate of the AMERICAN SUGAR INDUSTRY AND BEET SUGAR GAZETTE, 3,658,621 tons of beets, with a total output of 421,244 tons of sugar. Adding to this the round 300,000 tons of sugar derived from cane, we obtain a total of 721,000 tons of sugar produced in the Union during the past season. This quantity is somewhat imposing when we consider that the beet industry in this country is quite young. But, on the other hand, the amount of sugar produced equals only about one-fifth of the round 3,500,000 tons of sugar consumed last year in the United States. The figures representing the total production of domestic sugar fall still more into insignificance when compared with the 1,300 factories or so in Europe, turning out over 7,000,000 tons of sugar. What is, then, the trouble with the beet sugar industry in this country? It seems to us that aside from adverse legislation making the future of the industry uncertain, to say the least, the other main difficulties are to be found in the agricultural part of the industry as well as in the manufacturing part. A glance at the data given below is convincing as to the correctness of this opinion. The yield of beets per acre and the sugar percentage extracted from the beets was in the last three years as follows:

	1908-09.		1907-8.		1906-7.	
	Tons of beets per acre.	% raw sugar extracted.	Tons of beets per acre.	% raw sugar extracted.	Tons of beets per acre.	% raw sugar extracted.
Germany	10.9	17.5	12.1	15.7	12.8	15.7
Austria	9.7	17.2	10.2	16.4	10.6	14.7
France	10.8	12.6	10.2	12.9	10.4	13.5
Belgium	12.5	14.7	11.0	14.5	12.5	15.2
Average	11.0	15.5	10.9	14.9	11.6	14.8
United States	8.1	12.6	9.2	12.3	10.2	11.4

Thus we see that the tonnage for the last three years was considerably higher in each of the individual European countries than in the United States. This is also true of the sugar extraction. Further we find that the total average yield for the last three seasons in all four European countries was 11.2 tons per acre and the total sugar extraction for the same period was 15.1 per cent raw sugar, equal to 13.6 per cent white sugar, while the corresponding figures for the United States are 9.2 tons of beets per acre and 12.1 per cent raw, equal to 10.9 per cent white sugar, a difference of 2.0 tons of beets per acre and of 3.0 per cent raw, equal to 2.7 per cent white sugar in extraction in favor of the European countries. These data in our opinion prominently account for the whole situation of the American beet sugar industry. It must be borne in mind that the average cost of raising beets is from $30 to $40 per acre, hence it takes from six to eight tons of beets to cover all the expenses for beet seed, plowing, sowing, cultivating, harvesting the beets, etc. Speaking generally, it is only the yield *over* seven tons that constitutes the net profit of the beet grower. While the profit of the sugar beet growers is perhaps in the majority of cases higher than that from other crops, it is in some cases less. At any rate, it is evident from the above figures that the profit in beet raising greatly increases with each additional ton in the yield, as each such ton adds practically five dollars net profit. Similarly, it is easy to show that a certain extraction of sugar from the beets is required to cover the expenses for sugar manufacturing, and it is only the output *above* this extraction that makes the profit. Hence the whole problem is naturally confined to discovering means for increasing both the tonnage in field and the sugar extraction in factory, the capacity of the mill being also an important feature. If the American farmer could be taught how to get a greater tonnage than he obtains now and consequently to make more money with beets, he would be able to give the greatest possible impetus to the raising of beets.

In the following pages we shall discuss all the three questions that form, so to speak, the center of gravity of the whole industry. We shall also try to indicate the most recent developments in agricultural science for the benefit of the intelligent and progressive farmer on the one hand, and, on the other, be suggestive to the sugar manufacturer. In doing so we are very far from the thought of exhausting these important questions partly already treated in a number of articles in THE AMERICAN SUGAR INDUSTRY AND BEET SUGAR GAZETTE, since any one of them would require an extensive essay. But we hope that these pages may give rise to a series of articles from the pens of other writers, so that enough light will be thrown on the problems to make plain to interested parties the principles involved in raising beets and manufacturing sugar to better advantage. Not until these questions are solved, and solved in a thorough manner, will the beet sugar industry in the United States develop to an extent worthy of this country.

ELEMENTS NECESSARY FOR THE LIFE OF PLANTS.

Of the eighty elements or so known to the chemists and, as far as our present knowledge goes, known to constitute all organic and inorganic matter occurring in nature, only about ten are indispensable for the life of plants. Among these elements carbon, hydrogen, oxygen, nitrogen and sulphur are always, and phosphorus very often, absolutely necessary for the formation of proteins, the very material for building the protoplasm, the physical basis of life. The other four elements—namely potassium, calcium, magnesium and iron—have definite special functions to which we shall refer later. Of these elements carbon, hydrogen and oxygen occur, as is well known, in great abundance in nature in the shape of carbon dioxide and water, in the air as well as in the soil. The other elements—calcium, magnesium, iron and sulphur—are contained, as a rule, in sufficient quantities in the soil, where they occur in the shape of minerals or salts. There remain, then, only the three elements—nitrogen, potassium and phosphorus—in which many soils are deficient. These three elements, without which the beets can neither grow and develop to their natural size nor ripen, have justly been called the tripod of agriculture, since they are as necessary for the life of beets and of plants generally as are brain, heart and lungs—the vital tripod—indispensable for the life of animals. It is, then, natural that beet growers must pay their greatest attention to the presence of these elements in the soil. While, as mentioned already, nitrogen is an integral part of proteins and albuminoids necessary for the formation of protoplasm, it especially stimulates a large leaf growth. The importance of this phenomenon is evident from the fact that the beet leaves represent nature's chemical laboratory in which sugar is made.

The great physiological role of potash will be comprehended by remembering that it is by means of potash that the carbon dioxide and water taken up by the beet are converted—the co-operation of the chlorophyll granules in the leaves being necessary—into sugar or starch.

Of not less importance is phosphoric acid. Associated with the albuminoids or even constituting often an integral part of some proteins, and hence of the organs and tissues of the beet, it has been also found as a result of numerous chemical investigations that phosphorus is contained in seeds practically throughout the plant kingdom. The very ability of a plant to produce seed suggests its state of ripeness. And it is just the power of phosphoric acid to hasten the maturity of beets that is so highly appreciated in beet culture. Phosphoric acid or superphosphate—containing as such a certain amount of free acid—are naturally able to dissolve albuminoids and to facilitate their transference to the seed.

Although the quantity of iron found in the beet root and leaves is very small, nevertheless this element must be considered as absolutely necessary for the life of the beets and all other plants, since it is an integral part of the cell kernels, as was demonstrated by Stoklasa, and stands also in close relation to chlorophyll, by means of which sugar, starch and carbohydrates generally are formed.

One of the most prominent functions of calcium, especially in the beet leaves, consists in its ability to combine with oxalic acid with which it forms an insoluble compound. The importance of this function is easily comprehended by considering that free oxalic acid has an injurious effect upon the cell kernel, as was demonstrated by O. Loew. It further takes part in the formation of the cell membranes. To the influence of lime upon soil physics and biology we may refer later.

The functions of magnesium are considered as very similar to those of calcium. Generally it has been found that magnesium and lime may be substituted for each other in plants. In addition, according to latest researches, it is magnesium, not iron, that constitutes an integral part of the chlorophyll.

SOIL FERTILITY.

Having learned the most essential functions of the ten elements necessary for beets, let us consider now a question deserving our greatest attention, namely, soil fertility. It is in a sense the alpha and omega of agriculture. To maintain the fertility of the soil is or rather ought to be the chief problem of rational farming. When is a soil fertile? When it has the power to produce adequate crops. When has it this power? When the chemical, physical and biological conditions of the soil—of which more will be said—are in the right shape; provided, of course, that the climatic conditions are favorable. Since soil fertility includes so many conditions, it is conceivable that a general standard by which to measure the fertility of a soil does not exist, at least not at the present status of agricultural science. We know, however, that the fertility of the soil, or its crop producing power, depends not only upon the amount of plant food in the soil, but also upon its physical conditions; first of all upon its texture, with which are closely connected porosity, moisture, temperature, water moving power of the soil, the presence of bacteria in it, etc. Hence, in order to answer the question as to whether or not a soil is fertile, we must not only chemically analyze the soil but examine it physically and bacteriologically as well. Often farmers who stand on war footing with scientific agriculture and, therefore, sooner or later find their soil exhausted or worn out, send to their state experiment station a sample of soil for chemical analysis with the expectation of getting a definite answer as to why their soil is not productive. Of course, they will always get useful information and advice from the experiment station. In single typical cases they may even learn the actual cause of the trouble. For instance, if the chemical analysis has demonstrated deficiency of an essential plant food in available form, like potash for example, then the soil can be made more productive by fertilization with an ingredient containing the lacking element, provided the physical condition of the soil is all right. But in the majority of cases the chemical analysis alone won't do. Because only through the simultaneous examination by the soil chemist, soil physicist and soil bacteriologist can a thoroughly intelligent answer be given.

FERTILITY OF THE SOIL AS INFLUENCED BY ITS PLANT FOOD CONTENT.

Let us first of all examine the fertility of the soil from the standpoint of a chemist, *i. e.,* as far as the productiveness depends upon the plant food. Is there a standard by which to judge the fitness of a soil for beet growing? In this connection we should like to mention a correspondence between Mr. R. L. Adams, Director of Spreckels' Experiment Station, Spreckels, California, and the writer. Mr. Adams wrote to the Michigan Experiment Station that he was "anxious to secure a standard to judge the value of land for beet raising from the standpoint of chemical analysis" * * * asking what the station "considers the soil should contain in the way of nitrogen, phosphoric acid and potash * * * that is what percentage should the soil analyze to be good for production without requiring additional fertilization." * * * This letter was referred to us for reply which in some essential points was as follows: "There is no chemical standard for all cases enabling one to find out as to whether or not a soil is adapted to raising sugar beets or to judge the value of land for this purpose. In other words, if we know the chemical composition of the land we are not able as yet to positively state whether and in what degree it is fit for beet culture. This can easily be comprehended by taking into consideration that the beet crop depends not solely upon the amount of nitrogen, phosphoric acid and potash contained in the soil: the physical properties—such as texture, temperature and moisture of the soil—as well as the methods of its cultivation in connection with crop rotation have the greatest influence upon its productiveness. The surest means to ascertain the value of land for producing sugar beets will always be found in actual experiments. Raising beets on different parts of the land under investigation for one year, or still better for several seasons, the tonnage obtained per acre and the chemical analysis of the beets as to their sugar content and purity will always remain the best guide in the valuation of beet land."

As a matter of fact many investigations conducted by the Department of Agriculture as well as by agricultural colleges and experiment stations demonstrated the fact that practically in all cultivated or cultivatable soils, with few exceptions, there is an abundance of plant food. An ordinary farm soil contains in the neighborhood of 6,000 lbs. nitrogen, 9,000 lbs. phosphoric acid and 30.000 lbs. potash per acre-foot. The requirement of plant food for an average beet crop is quite insignificant when compared with these quantities, as a simple calculation will show us. Admitting the variation in the composition of the roots in certain limits, we can assume that beet roots contain about 0.15 per cent nitrogen, 0.07 per cent phosphoric acid and 0.35 per cent potash. Since the beet leaves are either left on the field or, when fed, their plant food is returned to the soil in the shape of manure, we are justified here in not taking the leaves into consideration. Hence, a crop of, say, twelve tons of beets to the acre removes the following quantities of plant food: 36.0

lbs. nitrogen, 16.8 lbs. phosphoric acid, 84.0 lbs. potash. Thus we see that the total plant food contained in ordinary farm soils is sufficient for continuous beet cropping for several hundred years. And yet practice has shown that even such lands very often do not give satisfactory crops. Why is it? The reason is that only a very small part of the total plant food is immediately available. What is available? Only the plant food that can be taken up by the beets and assimilated; and this is true of chemicals soluble in water or in exceedingly weak acid or salt solutions, such as occur in the soil. This is easily comprehended when we consider that all useful minerals—such as potash, lime, phosphates, etc.—are taken up by the plant through root absorption. No solids, necessary as they may be for the plant, can be taken up by it. Hence, all insoluble mineral food is useless for the time being. But later they may undergo certain changes through the action of various agencies in the soil, thereby becoming soluble and consequently available. Since such changes often require considerable time and as the growing period of sugar beets lasts only from four and a half to five and a half months, it is conceivable that the beets may be from time to time badly in need of certain minerals performing important functions in the life of the plant. This is the chief reason why an adequate supply of available or soluble plant food has always a beneficial effect upon the growth, development and ripening of the beets. Such available plant food can be had in the shape of natural and artificial fertilizers.

COMMERCIAL FERTILIZERS.

The polemic waged from time to time in literature as to whether manure or artificial fertilizers are more useful in raising beets or other crops is hardly worth considering. Both are powerful aids in intensive beet raising. Both materially improve the fertility of the soil and increase the yield of beets. While more will be said of manure in further pages we should like first to consider the commercial fertilizers. It is, it seems to us, worth while to discuss this subject somewhat at length, since the great importance of fertilizers for intensive beet growing has not been fully recognized in this country;

at least not in the West, where fertilizers are not used to any extent to speak of.

It was the great Justus v. Liebig, the father of agricultural chemistry, who, in 1840, laid down the chemical principles playing a vital part in the life of plants. In his famous book, "The Chemistry in Its Application to Agriculture and Physiology," he was the first clearly and precisely to pronounce that certain minerals are absolutely necessary for the life of plants. This recognized, he further pronounced that no soil can remain fertile for any length of time unless the minerals removed by continuous cropping are returned to the soil; that the state of agriculture in a country can be measured precisely by the phosphates (bone meal, superphosphates, guano and similar fertilizers) consumed. He even required of the German farmers to keep an accurate account of each field and to state how much of each mineral was given to or taken from the soil by certain crops. These and some other principles of Liebig, which have completely revolutionized the views that dominated in agriculture prior to Liebig, are as true to-day as they were seven decades ago. It is, therefore, to be regretted that one of the consequences of his doctrines, namely the necessity of application of artificial fertilizers in intensive beet farming, has not been adopted to its full extent in some sections of this country. Liebig's fundamental theories, modified by the latest discoveries of experimental agricultural science as applied to beet raising, will certainly have a beneficial effect upon this important branch of agriculture.

NITROGENOUS FERTILIZERS.

Though the amount of nitrogen in the air is unlimited, it is only the leguminous plants that have the power to feed on the free nitrogen of the atmosphere by the aid of certain micro-organisms. All the other plants are able to assimilate only the so-called combined nitrogen in the shape of ammonia, nitrates and so on. Since the amount of fixed nitrogen coming into the soil with rain, dew, snow, etc., is quite small, being annually about ten pounds per acre, which is only a small part of what is needed by most crops, the importance of applying artificial, nitrogenous manure is quite evident. But in what shape is it to be used? By virtue of the fundamental fact that the assimilation of plants is chemically speaking a reducing process, the plans are enabled to use, and do actually prefer as their food, the highest oxidation products occurring in nature—such as carbon dioxide (CO_2), water (H_2O) and nitric acid (HNO_3). The nitrogenous fertilizers found on the market contain nitrogen in three different forms—as nitric, ammoniacal and organic nitrogen. The nitric nitrogen, such as nitrate of soda or nitrate of lime, can immediately be taken and assimilated by the beet. The chief point to be emphasized here is the fact that nitrate of soda cannot permanently be absorbed by any soil. This, as well as its exceedingly ready solubility in water, renders it probable that a part of it will be lost by drainage after a rain. It is, therefore, not advisable to apply the total amount of nitrate of soda at one time, but rather to use it in several portions at different times. The scheme most favored in Germany is to use about one-third before or during the drilling, one-third after thinning and the last part during the following hoeings. Since nitrate of soda retards somewhat the ripening of the beets the last fertilization must not take place too late, say, not later than in the second half of June; as otherwise the beets will not have time enough to mature, and unripe beets, besides having a low sugar percentage, can be worked up in the factory only with great difficulty. The qualities of nitrate of soda make it admirably adapted for the West with its semi-arid climate.

The ammoniacal nitrogen is usually sold in the shape of sulphate of ammonia, a by-product in the manufacture of gas, coke and bone-black. While this chemical as such can be taken up by the beets, it is usually first oxidized in the soil to a nitrate, when it is absorbed by the beet roots. Sulphate of ammonia being not so easily soluble in water as nitrate of soda and being fixed in most soils, especially in clay and humus, is not subject to loss through rain. It is, therefore, more fit for the eastern states with their rainy climate.

Organic nitrogen—sold on the market as tankage, dried blood, dried fish, etc.—is changed in the soil chiefly through the action of bacteria, first into ammonia, then into nitrites and finally into nitrates, when the absorption by beet roots takes place. Organic nitrogen, as such, being not easily subject to loss through drainage, can be used advantageously in the East, although any one of the three nitrogenous types can be used in case of emergency throughout the country.

SUPERPHOSPHATES.

Phosphoric acid is sold as superphosphate, bone meal, acid phosphate, etc. It is best to use superphosphate which has always been a favorite fertilizer with the beet grower in Europe. The reason for its excellent influence upon the beet crop is, apart from its usefulness as such, probably due to the fact that being an acid salt it is able to dissolve a certain amount of other insoluble plant food contained in the soil and thus to make it available. The fact that superphosphate promotes the maturity of the beets is not to be underestimated. Superphosphate is usually distributed on the field in the spring shortly before drilling.

POTASH FERTILIZERS.

Potash is found on the market in very different salts, for instance as kainite, carnallite, sulphate of potash, muriate of potash and so forth. There must be positive determination not to use any potash fertilizers containing chlorine, wherever it can be avoided, since this element has a tendency to decrease the sugar content of the beets. If sulphate of potash cannot be found on the market, then kainite, containing less chlorine than either carnallite or muriate of potash, should be preferred. Muriate of potash, having the largest percentage of chlorine, should be avoided altogether. Whatever potash fertilizers may be used, they should be applied to the crop preceding the beet crop, or at least before winter, the reason being that the potash salts usually contain foreign matter which is advantageously removed through drainage before the potash proper can be absorbed by the beet roots.

In what quantities are the fertilizers to be applied? Since the chief aim of prudent farming should always be to maintain the fertility of the soil, it is obvious that all the mineral plant food taken from the soil must be returned to it. Our calculation above shows that a beet crop of twelve tons to the acre removes 36.0 lbs. of nitrogen, 16.8 lbs. of phosphoric acid and 84.0 lbs. of potash.

Now it must be taken into consideration that from 30 to 50 per cent of the fertilizer applied is lost, partly mechanically—for instance, through leaching out—and partly chemically—through formation of insoluble compounds with ingredients contained in the soil; hence the above figures should be correspondingly increased. In the intensive beet raising districts of Germany the farmers use about the following amounts to the acre: 40 lbs. nitrogen, 80 lbs. phosphoric acid, 120 lbs. potash. The reason for the use of a considerable excess of superphosphate in Germany is very likely to be found, on the one hand, in the fact that the phosphoric acid is capable of being distributed in a very fine state in the soil and, hence, of becoming easily accessible to the beet roots; and, on the other hand, in that it has the power to dissolve various insoluble substances contained in the soil and thus to render them available as food for the beets.

It is not possible, of course, nor is it necessary to consider here the economical side of the application of commercial fertilizers in detail. This topic is dealt with in many bulletins of state experiment stations in which valuable information regarding this question can be found. There is, however, one thing we should like to emphasize, namely, the fact that one pound of plant food—be it nitrogen, potash, or phosphoric acid—is cheapest in high-grade fertilizers and highest in low-grade ones. For instance, for the year 1908 in Michigan the average cost of one pound of nitrogen was in low-grade fertilizers 30.5 cents and in high-grade fertilizers 22.2 cents, a difference of 8.3 cents. Equally the average cost of one pound of either available phosphoric acid or of potash was in the low-grade fertilizers 8.2 cents, whereas in the high-grade fertilizers 6 cents. Thus, a Michigan farmer could save last year more than a quarter of his fertilizer bill by buying the high-grade fertilizers only. The conditions are similar throughout the country.

In order to ascertain whether or not a soil contains all the nourishment needed by the plants, the soil as such is usually analyzed. Such analysis gives accurate results as far as the total plant food is concerned, which, by the way, does not stand in any definite relation to the quantity of *available* food. Neither has such relation an acid extract of the soil. Of more value is the examination of a water extract. However, the execution of the analyses mentioned requires considerable time. We should like to call attention to the drainage waters in the fields. Such waters are very seldom, if at all, sent to experiment stations for analysis. And yet the examination of drainage waters, requiring less labor and time, will give very valuable information needed in order to answer the question with regard to the *available* plant food. If, for example, the analysis of the drainage water shows the presence of potash, then the application of potash fertilizers would be a waste of money. If no potash is found in the water then potash fertilizers should be used. Or if, for example, the drainage water contains in addition to potash also nitric acid, then the application of phosphates only is advisable. The presence of ammonia in drainage water would indicate that ammonia being formed through the action of bacteria in the soil cannot be absorbed by it. Under such conditions it is well to somewhat modify the texture of the soil by applying barn-yard manure or a green manure which will increase the humus of the soil and enable the same to fix the ammonia.

THE LAW OF MINIMUM.

Careful examinations of soils and drainage waters with regard to the available plant food are necessary in view of the law of minimum reigning in the vegetable kingdom. By virtue of this law it is the *minimum* of any essential plant food that is the measure of fertility. To illustrate: If there is in the soil enough available phosphoric acid and nitrogen to produce, say, fifteen tons of beets per acre and only so much potash as to produce not more than ten tons, then the actual crop will consist of only ten tons of beets. The excess of nitrogen and phosphoric acid will be, so to speak, idle, and the nitrogen will eventually be lost through drainage after it has been oxidized to a nitrate for which no soil has a permanent absorptive power. Hence, the importance for the farmer to know what his soil contains and in what proportions.

BARNYARD MANURE.

Concerning barnyard manure, the farmer may distribute on the fields to be brought under beet cultivation all the manure he has. We do not think that an average farmer has more than ten, or at most twenty, tons of manure to spare for each acre; in the majority of cases he has less, and it is just in such instances that the lacking manure should be supplemented with artificial fertilizers. The manure, however, should be used judiciously, first of all at the right time. It is best to apply it to the crop preceding the beets or at least to plow it under early in the fall. That way the manure will have time enough to decompose quite completely, the organic nitrogen to oxidize to nitrate, when it becomes available. Barnyard manure is valuable not merely on account of the potash, nitrogen and phosphoric acid present, but probably just as much for the reason that it improves the texture-of the soil, it increases its humus content and, consequently, its water holding capacity as well as its absorptive power for ammonia. In addition, the manure darkens the soil, enabling it to absorb more of the sun's rays and hence making it warmer, which is especially important for the early germination and development of the young beetlets. Moreover, it introduces into the soil countless bacteria which are beneficial to the soil in a good many ways, as for the nitrification of the organic and ammonical nitrogen, for the oxidation of vegetable matter, which processes generate acids dissolving a certain amount of soil ingredients and making them available for the nutrition of the plants.

The application of manure and of commercial fertilizers in beet raising countries is the consequence of numberless experiments, observations and results obtained with the sugar beet during more than half a century. Out of the great mass of evidence as to the effect of manure we wish to cite only a few instances. The effect of manure upon the tonnage can be seen from the experiments by *Liebscher* in Germany:

Manure per hectare. Kilograms.	Yield per hectare. Kilograms.
None	31,065
20,000	34,785
30,000	35 435
40,000	42,100

The quality of the beets remained in these experiments practically the same. Recalculating these figures we find that the application of 15 tons manure to the acre—which is reasonable—added to the crop more than three tons of beets.

Wagner's experiments in the same country have demonstrated that 100 kilograms Chili saltpeter with 15½ to 16 kilograms of nitrogen increase the crop about 4,500 kilograms of beets and 900 kilograms of leaves per hectare. Recalculating these data and recalling that one ton of Chili saltpeter costs sixty dollars, or about nineteen cents per pound of nitrogen, we find in round figures that $2.60 worth of saltpeter added to the crop two tons of beets to the acre, thus leaving a considerable net profit. Similar experiments could be quoted by the hundreds.

In the face of these data it is, then, logical to suppose that the American farmer readily uses fertilizers and takes good care of his barnyard manure, since their beneficial effect upon soil and crops are so important and manifold. It is, therefore, all the more strange that the following facts can be stated. It is estimated that by leaching from manure on American farms an amount of plant food—that could be easily saved—is annually lost which is equivalent to $200,000,000. Furthermore, practically all the nitrate of soda found on the world's markets is derived from the American continent. However, it is Europe, not this country, that uses the lion's share, as will be seen from the following figures given in the American Fertilizer Hand Book, 1908, page 78:

Consumption of nitrate of soda in metric tons.	1895.	1900.	1905.
United Kingdom................	117,500	135,000	101,000
Continent of Europe............	789,500	991,000	1,089,000
United States....................	110,000	175,000	320,000
World	1,024,000	1,324,000	1,559,000

Thus we see that even in 1905, when the United States used relatively the largest amount of sodium nitrate, this country's share was only one-quarter the amount consumed in Europe. In his book mentioned above, J. v. Liebig deplores the export of bones from Bavaria to Saxony, not hesitating to call it a robbery committed on the Bavarian fields and predicting sad consequences for the beet sugar industry. How much more is it to be regretted that the still more valuable nitrate of soda is exported from the American continent to all countries of the world. The significance of this fact will be perhaps better comprehended bearing in mind that the other principal nitrogenous fertilizer—the sulphate of ammonia—is produced practically only in Europe, this country producing 12.2 per cent, while the production in the European countries equals 87.8 per cent of the total amount.

However, in using artificial fertilizers or barnyard manure, it is of the utmost importance to apply them judiciously, i. e., the proper amounts and at the right time. To rich land having enough plant food no fertilizers should be applied, since the inconsiderably increased tonnage, if this be the case at all, will hardly pay the extra expense for the fertilizers. Barnyard manure ought to be used early in the fall to give a chance to the organic nitrogen to oxidize, at least partly, to nitrates, the presence of which is especially important for the young beetlets to get a vigorous growth. When manure is applied late in the spring the plantlets failing to find in their early development the necessary food, are not able to get a good start and will take up the nitrates much later. As a consequence the beets will not be ripe in time, and will contain a considerable percentage of non-sugars, representing a poor raw material for sugar making. This is also true of artificial nitrogenous fertilizers, which should not be applied too late, since the maturing of the beets would be equally retarded. The value of systematic and rational application of fertilizers, be they natural or artificial ones, which should supplement each other, lies in the fact that they preserve the fertility of the soil enabling one to get adequate crops, not only occasionally, but year for year, and not only of the beets alone, but of the rotating crops as well.

CULTIVATION OF THE SOIL.

The amount of artificial and natural fertilizers can very materially be reduced without disadvantage through the proper kind of tillage operations, which is important in view of the fact that commercial fertilizers mean certain expenses and manure is often not to be had in sufficient quantities. First of all deep plowing is essential. Besides loosening and aerating the soil, increasing its water holding and water moving capacity, which is of great moment, as the soil is then better enabled to meet the needs of the crop, deep plowing means also a better and more thorough utilization of the chemicals contained in the lower layers of the soil. It will enable the beet to go down deeper into the soil, and to get water and food when necessary. It will increase not only the beet yield, but benefit the succeeding crops as well. A farmer who is accustomed to shallow plowing reminds us of one who keeps a part of his capital hidden, instead of utilizing it. What would a farmer say when advised by somebody to cultivate only a part of his soil and to allow the rest of his good cultivatable land to lie idle? Or how would he like the suggestion not to use his farmyard manure on the fields but simply to throw it away? We don't think he would like such ideas. But this is exactly what he does when he plows only shallow. In Germany they plow as deep as sixteen and eighteen inches. In this country, namely in some of the western states, we saw a good many fields plowed only to a depth of seven to eight inches, and such fields were brought under beet cultivation. True, one must not plow so deep as to bring to the surface several inches of subsoil in one season, since the dead soil being poorer in humus and available plant food would materially impair the soil and hence diminish the crop at least for one season. But one to one and one-half inches of subsoil could and should be added to a shallow soil each season. This would hardly diminish its productiveness. Through nature's agencies, such as oxygen, ozone and carbon dioxide, through rain, snow, humic acids and bacteria, as well as through the tillage operations, the insoluble plant food of the subsoil will be rendered available, humus increased, and thus the subsoil will gradually be changed into soil. In a few years the shallow soil will be converted into a deep soil entirely fit for beet culture as well as for other deep-rooting vegetables. The absolute necessity of deep plowing for raising beets lies in the fact that they are deep-rooting plants, having the tendency to penetrate deep into the soil, and where the soil is not deep enough the beet roots are turned aside from their natural direction, become misshapen and in addition grow out of the soil. Such beets are deficient in sugar content and purity, as has been demonstrated by numerous experiments. Furthermore, countless chemical analyses of soils have conclusively shown that the upper part, say, eight inches, does not contain much more plant food than the next lower ten inches. Even the subsoil proper has practically the same quantity of ingredients, although not in available form. This being true, it means, figuratively speaking, that a German beet grower utilizes his land twice as effectively as do some western farmers, as far as plant food is concerned.

Fall plowing is of great moment, inasmuch as it enables the soil to take up all the precipitations that will fall during the autumn and winter. A soil with hard, compact surface will allow most of the water to run off and go to waste. On the other hand it allows the excessive water to penetrate into the subsoil. Through fall plowing the loosened soil is for several months advantageously exposed to the influence of air, light, rain, snow, temperature variations, which agencies, as mentioned above, convert the unavailable, so to speak, distasteful plant food into the assimilable form that can be taken up by the beets. In addition early plowing in the fall will prevent weeds from going to seed.

Rational rotation is one of the fundamental principles of scientific agriculture. Since the rooting habits of various crops are different and the roots are the organs to absorb the dissolved mineral substances, it is clear why rotation gives an excellent means to keep under tribute the soil in its whole cultivatable depth as far as plant nourishment is concerned. While a soil may be exhausted for shallow rooting plants, it can contain still lots of food for deep rooting crops like the sugar beet. The very fact that various crops remove different quantities of different elements, that the beet crop, for instance, removes less nitrogen and phosphorus than a corn crop, that barley removes more potash than wheat, etc., suggests that it is only through a prudent rotation that the plant food in the soil can more completely and systematically be utilized. Rotation essentially improves the texture of the soil, the stubbles and roots remaining from various crops in the soil at different depths furnish by decay humus which is beneficial to the soil in many ways. That proper rotation of crops destroys a good many weeds and prevents in a large measure the accumulation of insects, fungi and a score of beet diseases is a well known fact. And yet some sugar companies anxious as they are to cut in their mills as many beets as they possibly can get, are growing beets on the same land year after year to find finally their soil exhausted. In a few instances, it is admitted, some farmers may get good beet crops for several years in succession, but on the whole a system without rotation is not prudent and will give in the majority of cases smaller tonnage and poorer beets.

Here it was our intention to discuss a number of questions, namely: the physical, chemical and biological role which lime plays in the soil, the modern scientific means by which nitrogen is accumulated in the soil, the late experiments showing the ability of sodium to replace potassium to a certain degree, the importance of thinning at the right "psychological moment," the importance of frequent hoeing by which operation, as the saying goes, "sugar is hoed into the beets," and some others. But since practically all these topics have meanwhile been treated in The American Sugar Industry and Beet Sugar Gazette by other writers and treated in a quite thorough and able manner, we wish to eliminate them altogether. There is, however, one topic which we should like to touch upon once more. It is the question as to whether sugar beets exhaust the soil.

DO SUGAR BEETS EXHAUST THE SOIL?

Since the above question is of vital importance to every beet grower we feel that it is worth while to make every effort to shed upon it as much light as possible. The American farmer upon whose willingness and readiness to grow beets rests in the last analysis the great beet sugar industry to be created in this country, has a right to know everything concerning this paramount question. Let us, then, find the truth by a careful analysis. In saying that a crop exhausts the soil we have in mind, first of all, the amount of plant food removed by it. Does a beet crop remove more plant food than other crops? The answer to this question we find in the following table:

AMOUNT OF FERTILITY REMOVED FROM AN ACRE.

Kind of Crop.	Yield.	Nitrogen.	Phosphoric Acid.	Potash.
Sugar beet	10 tons	30 lbs.	14 lbs.	70 lbs.
Tobacco	1,600 lbs.	76 lbs.	16 lbs.	200 lbs.
Corn	40 bus.	56 lbs.	21 lbs.	23 lbs.
Wheat	20 bus.	41 lbs.	13 lbs.	17 lbs.
Oats	40 bus.	40 lbs.	14 lbs.	33 lbs.
Barley	30 bus.	56 lbs.	17 lbs.	51 lbs.
Clover hay	2 tons	82 lbs.	18 lbs.	88 lbs.

Thus, it is readily seen that the beet takes from the soil the least amount of nitrogen which is the most important and the most expensive element, that this holds also true for phosphoric acid with the exception of wheat and oats taking from the soil practically the same amount of phosphorus as does the beet. It is only the potash of which a beet crop removes more than some other crops, but it requires less potash than tobacco and clover hay. The fact that the sugar beet removes less fertility from the soil than a good many other crops together with the prudent methods of cultivation used in beet growing account for the phenomenon that the beet used as a rotating crop increases the yield of most other crops; it raises, for instance, the yield of rye, wheat and barley 15, 24 and 25 per cent in the order named. How can the above remarkable facts scientifically be explained? Nothing is easier than that. Sugar is a carbohydrate and consists of carbon, hydrogen and oxygen only. Fortunately these elements do not cost the farmer a cent, as the wise bounteous nature furnishes the same in great abundance in the shape of carbon dioxide and water. But in addition to the sucrose there are some other elements which are contained in the beet, namely potassium, phosphorus, nitrogen, lime, magnesia, etc. These elements form in the beet and hence in the sugar juices the so-called mineral non-sugars found later as ash in the meladas, second and third products as well as in granulateds and giving rise to the formation of molasses. And it is just these non-sugars that exhaust the soil, making at the same time a poorer grade of beets both in sugar percentage and purity. Such non-sugars, exhausting, as they do the soil, must be returned to it by the use of manures and fertilizers. It is, then, evident that if it would be possible to raise an ideal beet consisting of pure sugar juice, i. e., of sugar and water only, the soil would not be exhausted at all, no fertilizers would be needed after a beet crop. While this is an impossibility as some nitrogen, phosphorus and potassium are absolutely necessary for the formation of protoplasm, of seed and of the sucrose itself, the tendency must be alive to reduce the amount of non-sugars in the beet to the very minimum. The question naturally arises as to whether we have the means to attain this purpose. Fortunately this question can be answered in the affirmative. The proper selection of the beet seed, of the right kind of soil, further judicious fertilization and thoroughly scientific modes of cultivation are here of the greatest moment. The history of the sugar beet shows that with increased knowledge and experience in beet growing the non-sugar content of the beets was gradually diminished. In Dr. A. Ruempler's *"Die Nichtzuckerstoffe der Rueben,"* p. 15, we read that in 1871 the fresh beets contained 0.772 per cent of ash and the dry substance contained 3.86 per cent of ash, while the average for the ten years from 1870 to 1880 was as follows:

0.754 per cent of ash in the fresh beets and 3.77 per cent of ash in the dry substance of the beets.

This decrease of the non-sugars in the beets went on so that for the years from 1892 to 1894 the average was:

0.578 per cent of ash in the fresh beets and 2.73 per cent of ash in the dry substance.

Thus, in about two decades it was possible to diminish the ash content from 3.86 per cent to 2.73 per cent calculated on the dry substance of the beets, or 29 per cent of the total ash content .

The conclusions to be drawn from the above data are, it seems to us, quite instructive. The object of sugar beet raising is in the first place the sugar which has been recognized as an important article of human diet. This should be kept in mind by the farmer. Everything that leads to the increase of sucrose in the beet is advantageous not only for the sugar manufacturer but for the farmer just as well. A beet grower who raises the best, purest beets exhausts *least* his soil; a farmer raising poor beets exhausts *most* his soil. Here the interests of sugar factory and beet grower are *identical.* This is also true in a large measure with regard to the tonnage. Generally speaking medium-sized beets of, say, from one to two pounds usually give the best tonnage. Such beets have, as a rule, also higher sugar content and purity than large-sized beets. This natural identity of the interests can and should be promoted by all means at the command of the industry. If beets would be paid not flat rate, as is the case in many factories, but according to sugar percentage and purity all parties concerned would be benefited alike, since a crop of high-grade beets takes the least amount of fertility from the soil and at the same time the manufacturer gets the best possible raw material for the production of sugar. If further the farmer would *systematically* be encouraged by prizes for beets of the best quality as well as for largest tonnage harvested and also be allowed to directly participate in the profits of the sugar companies, the means by which the European beet industry has reached its enormous size would practically be completed. The same means would undoubtedly have the most beneficial effect upon the American beet industry as far as tonnage and sugar percentage in the beet are concerned. Here, however, we are confronted with the momentous question as to whether the sugar percentage in the beet can still further be increased, or, to express it in other words:

HAS THE SUGAR CONTENT IN THE BEET REACHED ITS LIMIT?

Some writers are inclined to believe that such is the case. But is it? Contrary to this opinion we do not think that this limit has been reached. Certain it is that forty years ago nobody would have dared to foretell that it would be possible to produce beets with a sugar percentage of from 20 to 25, which is now actually the case. Nor is this the limit. Nature finds means to produce plants with low as well as with high content of carbohydrates. The potato with 20 per cent of starch, wheat with 60 per cent, and rice with 70 per cent, as well as the oak, beech, pine and black poplar with 40, 45, 55 and 63 per cent of cellulose respectively, may represent plants with a considerable variation of starch and cellulose content. Beets, potatoes and trees! Sugar, starch and cellulose! What relation have they to each other? Sugar, starch and cellulose, it is perfectly true, are physically quite different, chemically, however, they are closely related to each other as can be seen from their formulas:

$C_{12}H_{22}O_{11}$	$(C_6H_{10}O_5)_n$	$(C_6H_{10}O_5)_x$
Sucrose.	Starch.	Cellulose.

They all are carbohydrates, they all consist of carbon, hydrogen and oxygen only, they all contain hydrogen and oxygen in the same proportion which we find in water, as well as six or a multiple of six atoms of carbon. When treated with dilute sulphuric acid they are converted into the same glucose, at least partly. This simply shows how far reaching is the analogy between sugar, starch and cellulose in chemical respect. The question as to where lies the limit of the sugar content in the beet could be answered more precisely if only physical and chemical conditions were involved. But in addition to these the rather complicated physiological functions in the beet must also be taken into consideration, which differ, of course, in plants with various carbohydrates. However, it is perhaps reasonable to assume that as long as the sugar cannot crystallize out in the juices of the living beet plant its physiological functions may not seriously be interfered with. Which is, then, the solubility of sugar in water? At room temperature one part of water dissolves about two parts of sugar, the exact figures being as follows:

At 0 deg. C 100 parts of water dissolve 179.2 parts of sugar.
At 15 deg. C. 100 parts of water dissolve 197 parts of sugar.
At 40 deg. C. 100 parts of water dissolve 238.1 parts of sugar.

The temperatures 0° and 40° C. fairly represent the extreme temperatures to which the plant may be subjected during its growth, 15° C. being near to the average temperature. The least solubility of sugar in water is at 0° C. at which temperature 1.79 parts of sugar saturate 1 part of water, representing a solution with 64 per cent sugar. This means that as long as the sugar percentage is below 64, the sugar cannot crystallize out in the cells of the living plant. True, the beet juice is not a pure sugar solution; it contains also salts and generally speaking nonsugars somewhat modifying the solubility of sugar in water. Nor have other conditions been taken into consideration. But the above contemplation gives some suggestion that we have not by far arrived at the limit of the sugar content in the beet.

We do not believe, of course, that with our present knowledge and means we shall ever get beets with, say 50 or 60 per cent of sugar, and while it is an ungrateful task to be a prophet, we nevertheless do not hesitate in stating that the beets are still capable of being improved very essentially, provided strictly scientific methods will be applied. It was only after the fruitful ideas of the great Charles Darwin that plant breeding was taken up scientifically. Through such methods it was, for instance, possible to materially increase the starch content in potatoes, the protein content in corn, or at will to breed corn with high and low protein content. As far as the sugar beet is concerned its improvement in quality was practically accomplished in the last four decades. We know already (see page 5) that in 1872-3 the sugar percentage extracted from beets in France was 5.70 and in Germany it was 7.93 for the year 1866-7. At present all sugar factories reject beets with less than 12 per cent sugar. Beets with a sugar content of from 14 to 18 are common and some factories are cutting beets, some of which have from 18 to 20 per cent sucrose. Even beets with a sugar percentage of from 20 to 25 are by no means very rare. Thus, the sugar percentage of the beets was trebled and can be said to have increased from one to two per cent per each decade. At the same time the purity rose from 65 to 75 in the beets of olden times to as much as 80 to 90 in the beets of to-day. And if the improvement of the beet continues—which is reasonable to assume—we may expect that in half a century the sugar beet will have, say, an average sugar percentage of 20 and a corresponding high purity. This is by no means out of the question recalling the fact that through proper modes of selection and cultivation it was possible in the past to fix definite properties in the beets. So the leading beet seed growers succeeded in producing certain types, like the "Improved Vilmorin" with a high sugar content, the "Klein Wanzlebener" with a large tonnage, the cross beet of these two types with both high sugar percentage and big tonnage. Generally it was possible through prudent, rational methods to treble the sugar content of the beets and to breed such with 20 to 25 per cent sugar and high purity and there is absolutely no reason why these qualities could not be fixed so as to make them common for the majority of the progenies through the above indicated means.

Time does not allow us to go into details. But take, for example, the beet seed. The very choicest seed is none too good. A higher price for seed does not count here. Five cents more per pound of seed means a larger expense of only one dollar to the acre, but good seed insures more beets and better beets. The fact must be borne in mind that the present sugar beets of high sugar content and purity are the result of careful selective and cultural methods and originate from beets that are now justly called feed beets. There can be no question but that the amelioration of the beet can and will go on still further to the advantage of both beet grower and sugar manufacturer for many years to come.

Now we wish to take up the other part of this publication, namely the manufacture of sugar from beets. Inasmuch as the modern sugar manufacturing process nowadays represents quite a science, it is out of the question to deal with all its phases in a paper of this kind and it may be said right here that we are not going to announce any new great inventions or discoveries. After all even in a modern mill all the processes, like the diffusion, defecation, carbonatation, the Bock process (crystallization in motion) etc., are old, though gradually improved, processes known already for a number of decades. Our purpose is simply to lay down a number of observations and practical experiences, made by us during a number of years, for the benefit of those connected with the beet sugar industry, and in doing so we shall in the following pages try to touch upon the most vital parts of the manufacturing process. We shall try to show how the capacity in a sugar mill can be increased, the sugar extraction improved, or how the most important calculations in a sugar mill can be performed in a simple and easy manner.

THE CAPACITY OF A SUGAR MILL.

The capacity of a mill and the sugar extraction are undoubtedly the two great focuses upon which all the thoughts of the managers and superintendents are naturally concentrated. Generally speaking all the care and work in a sugar house have or ought to have as their final objects: first, to cut as many beets as possible in 24 hours (full capacity), second, to extract the maximum percentage of sugar from the beets (complete extraction), third, to produce sugar of the highest quality, and to perform all these operations in the most economical way. A mill in which all these purposes can be achieved is in a first class condition. But the achievement of two of the objects named must be required of any management, if the sugar factory is to run with reasonable profit. The importance of full capacity can be illustrated by a simple calculation, and while the expenses in a small mill are comparatively greater than in a large one and conditions naturally change with the location and special circumstances in each sugar factory, the following figures may be considered as an approximate statement for sugar works in this country. Let us take for this calculation, e. g., a sugar factory of 600 tons daily capacity, cutting 50,000 tons of beets during a campaign of 85 days. The expenses are then in round figures as follows:

85 days × 200 people (including unloading and siloing beets) × \$2.00 a shift	\$ 34,000
Coal (18%) $= 50{,}000 \times \frac{18}{100} \times \$2.75$	24,750
Salaries of permanent employees per year	18,000
Workmen outside of campaign: 10 people × 6 months × 25 days × \$1.75	2,625
Amortisation (including interests) of capital: 450,000 × 4%	18,000
Sugar bags and barrels (including packing), about	20,000
Repairing of machinery, apparatus, etc	8,000
Lime rock, coke, oil, filter cloth, light, etc	20,000
Taxes, insurance and general expenses	20,000
Total	\$165,375

Hence, according to this calculation it costs $\frac{\$165{,}375}{50{,}000}$ or \$3.31 to convert one ton of beets into marketable sugar.

The cost of sugar manufacture can be calculated also in another way: Since 1 ton of beets furnishes 11 per cent or 220 lbs., of sugar, we find that the cost of sugar in the raw material is $\frac{\$5.00}{2.20} = \$2.27$ per 100 lbs., on the other hand the selling price is about $4.50 per 100 lbs. The balance of $2.23 represents the cost of production plus profit. Allowing from 10 to 15 per cent profit, we find that cost of production is about $1.60 per 100 lbs. sugar or $\$1.60 \times \frac{220}{100} = \$3.52$ per ton of beets.

Consequently, on the average it costs about $3.40 to convert 1 ton of the raw sugar material into granulated. Now, if through inexpensive improvements and rational running of the mill its capacity can be raised, say 20 tons per shift or 40 tons in 24 hours, it would mean that in a campaign of 85 days duration, 3,400 tons of beets can be cut without cost, as the expenses for labor, coal, oil, etc., remain practically the same. These 3,400 tons of beets cut thanks merely to the raised capacity of the mill represent a higher net profit of $3{,}400 \times \$3.40 = \$11{,}560$.

In discussing the question of how to increase the capacity of a sugar factory we have in mind a few simple and cheap means which can be applied in any sugar plant. Hence, the reconstruction of a whole sugar factory or even of a larger part of it is beyond the frame of this publication. In order to more intelligently grasp the ideas of how to raise the capacity of a sugar plant we must comprehend what the capacity of a mill really means. A sugar mill has actually a daily capacity of 600 tons when each and every department has this capacity, i. e., when the diffusion battery can extract the juice from 600 tons of beets, the carbonators purify, the presses filter, the multiple effect evaporate and so forth. But, be it well understood, the capacity of a mill is not given by the average capacity of the various stations. If, for instance, the beet end has a capacity of 580 tons of beets and the sugar end one of 620 tons, the mill is not able daily to work up 600 tons of beets. The same holds true when the reverse is the case. The capacity of a sugar factory is determined by its weakest department.

In case a mill has only one, two or even three of such stations it is, as a rule, not difficult and for economical reasons it is imperative to raise their capacity to the height of all the other stations.

What is true of the mill as a whole holds good also for each separate department. The capacity of each department is fixed by its weakest part. For example, the speed of the juice circulation in a diffusion battery is given by its least velocity in an overheated or "plugged" cell. The speed with which the juice is transported from one station to another is given by the pipe of the *smallest* diameter. Hence, if through a mistake or some other cause a 5 inch pipe line has one single pipe of 4 inch diameter, then the transportation of the juice in that line will practically take place with a velocity corresponding to a 4 inch line.

While it is a rather easy matter to increase the capacity of a beet wheel, of a beet and pulp elevator by simply raising their speed or by increasing the number or size of the buckets, it is somewhat more complicated when we have to do with departments commencing with the diffusion battery down to the sugar end.

THE DIFFUSION BATTERY.

We do not have here in mind the increase of the capacity of the diffusion battery by adding two or more cells which is easily performed in a straight battery and with more difficulty accomplished in a circular one. Nor do we think of a change of the whole pipe system in a battery which change, when the pipe lines are not wide enough, is in some special cases very useful and even indispensable. A consideration of the fact that a pipe system of 7″ diameter will *caeteris paribus* pass about twice as much juice than one of 5 inches shows at once the importance of a wide pipe system. Both remedies, however, are expensive. A battery given in a sugar factory with the number of cells and the pipe system unchanged can be made to work up more beets by some plain but nevertheless effective means.

The capacity of a battery, just as it *exists* in the factory, depends chiefly upon the velocity with which the raw juice is able to move in the cells. This again depends upon a number of conditions. In the first place there are always gases in the battery retarding the circulation of the juices. Inasmuch as this question is of considerable importance and has not been fully treated even in such well-known books, like Dr. Claassen's "Zucker-Fabrikation," Stohmann's "Handbuch der Zuckerfabrikation" and Dr. Stammer's "Lehrbuch der Zuckerfabrikation," it is, it seems to us, worth while to longer dwell upon this subject. The gases mentioned accumulate chiefly in the upper parts of the cells and heaters and have the tendency to stay there by virtue of their low specific gravity. It is obvious that they must constantly be a hindrance to the downward moving juices and in that way diminish the speed of circulation. This is the reason why it is necessary to prevent the formation of gases in the battery and, when formed, to remove them. Where do the gases come from? First of all there is some air in the chips as well as a certain amount of carbon dioxide contained in the beet juice. These gases are always more or less to be found in a battery. More injurious or undesirable is the hydrogen produced through the chemical action of the slightly acid diffusion juice upon the iron sheets of the cells. The acid reaction of the raw juice is due to the presence of a number of organic acids or their salts naturally occurring in the beet juices, like the acids: glycolic, oxalic, malonic, succinic, malic, tartaric, citric and others. The above chemical action can be illustrated by the following equation:

$C_2H_2O_4$	+	Fe	=	C_2FeO_4	+	H_2
Oxalic acid		Iron (cell material)		Iron oxalate		Hydrogen

Hydrogen, together with carbon dioxide, can also be formed through the activity of bacteria coming into the cells mainly with dirt adhering to the beets. The micro-organisms cause fermentation of the raw juice, and as a consequence sugar is decomposed into organic acids under development of hydrogen and carbon dioxide. This decomposition represents very likely the butyric or lactic fermentation, as expressed by the following reactions:

$C_6H_{12}O_6$	=	$2CO_2$	+	$C_4H_8O_2$	+	$2H_2$
Glucose		Carbon dioxide		Butyric acid		Hydrogen

or: $C_6H_{12}O_6 = 2C_3H_6O_3$
Glucose, Lactic acid,

and the lactic fermentation can then be converted into butyric fermentation as shown in the equation:

$2C_3H_6O_3$ =	$2CO_2$ +	$C_4H_8O_2$ +	$2H_2$
Lactic acid	Carbon dioxide	Butyric acid	Hydrogen.

How, then, can these injurious gases be removed? In the first place it is wise to prevent the formation of the gases, and this can be done in a simple way. All that is necessary is to paint the inside walls of the cells before the campaign starts. Covering with a coat of red lead is preferable to that of white lead since the latter is more easily attacked by the acids of the raw juice. Even covering with boiled oil containing little paint will do some good. These means will in a large measure prevent the formation of hydrogen. More than that, they will prolong the life of the expensive diffusion battery two, three or more years. It is, therefore, to be regretted that there are a good many factories failing to make use of this preventive measure. The cost for paint and labor is not significant when compared with the benefits derived.

Concerning the fermentation and gases due to biological processes it is best to prevent them by thoroughly removing the dirt from the beets in the washer and by using pure water for pressure in the battery. Where the beet washer is not large enough to thoroughly wash the beets, it is necessary to keep the raw juice hot in as many cells as possible. For this purpose it is best to make connections in the battery enabling one, when necessary, to divide it into two separate batteries which can be accomplished without any difficulties in a straight line battery. The high temperature in many cells will partly kill the microörganisms, partly reduce their activity to a minimum.

However, a certain amount of gas, chiefly air and carbon dioxide which has been in solution in the living cells of the beets, is always contained in the battery. One can most conveniently get rid of those gases through apparatus automatically removing the air and other gases from the upper parts of the heaters. Where such air removing apparatus are not present, we have found the following measure quite effective: On the air cock of each cell a bucket is allowed to hang. The boy assisting the battery man goes along the cells and opens once in a while the air cocks one after another. Each cock is kept open until all the gas is removed and juice begins to flow, when the cock is immediately to be closed. Then the next cock is opened and so forth.

In mashing the cell containing fresh chips with juice from the preceding cell, it is of some advantage to perform two-thirds or more of the mashing with open lid, and to close it only at the end of this operation. That way the air flows out somewhat more rapidly and thus the operation of mashing is accelerated in some degree.

With a good strong screen, having a maximum free passage, at the bottom of each cell—which is exceedingly important—and with the gases removed, the speed of the juice circulation in a battery depends solely upon the available water pressure on the one hand and the contra-pressure on the other. As far as pressure is concerned it is best to have such from a tower tank. If this is not to be had, then a centrifugal pump is preferable to a piston pump. In the first two cases the water pressure is more uniform and constant than in the last named case. For a number of reasons the pressure must not be too high, say, not more than from 14 to 18 lbs., per square inch. But the contra-pressure from the measuring tanks can be changed practically at will. In a good many factories the diffusion measuring tanks are placed in such a way that their bottom is above the diffusion battery, the only advantage being that the raw juice can flow from these tanks into the carbonators through natural gravity. But it is evident that the contra-pressure from the measuring tanks retards the juice circulation in the cells, in other words it diminishes the working capacity of the battery. Wherever this arrangement is to be found, it should unhesitatingly be changed. This can be done in two ways: either the measuring tanks are lowered to the level of the diffusion battery which requires then a circulation pump to transport the raw juice from the measuring tanks to the carbonators, usually through calorisators, or the measuring tanks are left where they are and between them and the diffusion battery a centrifugal pump is placed which pumps the juice from the battery into the measuring tanks. While both arrangements will accelerate the work in the battery, the last mentioned scheme is more effective and to be preferred the reason being that in the latter case there is in the battery pressure from one side and suction from the other. This double action considerably increases the speed of the juice in the battery. We know of cases in the practice where the daily capacity of the battery was increased through that arrangement from 30 to 50 tons of beets and more. The dimensions of the pump to be placed between battery and measuring tanks can easily be calculated when we know the work it has to do. The draw per one ton of beets is about 10 hectoliters raw juice. In a mill of, say, 600 tons daily capacity there are produced in 24 hours 6,000 hectoliters which the pump must transport from the battery to the measuring tanks. In other words, the pump must have a capacity of $\frac{6000}{24 \times 60} = 4.17$ hectoliters per minute. It is good to take the pump from 10 to 20 per cent stronger than the theory requires.

But one more fact, and one of considerable value, we should like to mention in connection with the battery. It is of paramount importance to fill each cell with chips to its utmost capacity. It is not right to start packing the chips with a stick when the cell is already full. This operation should begin as soon as the cell is more than half full and should last without interruption up to the last moment when the cell is quite full. The packing should be done by a powerful man by means of a stick strong and long enough to reach deep into the cell. The great importance of this manipulation can be seen from the following consideration: The difference between a well and negligently packed cell is from a quarter to half a ton of cossettes and more; the larger the volume of the cells, the greater is this difference. By careful packing it is in many factories within reach to fill into each cell on the average a quarter of a ton chips *more* than is now the case. By working up 160 cells in 24 hours it will be possible to cut 40 tons of beets more. For a campaign of 90 days it makes $40 \times 90 = 3,600$ tons of beets. The conversion of the 3,600 tons of beets into sugar does not cost the factory a cent! Cost for labor, fuel, lime rock, coke, etc., remains practically the same whether the cells are packed or not. More than that: through careful packing the diffusion juice is more concentrated, has a higher purity and the circulation is also somewhat improved. All the above recommended means, simple and inexpensive as they are, allow to reach the maximum capacity in a diffusion battery.

THE CARBONATORS.

From the standpoint of the capacity of a sugar mill it does not make any difference whether there are 10 carbonators of 700 cu. ft. or 7 carbonators of 1,000 cu. ft. each and so forth. With proper arrangements for heating and saturating the juices with gas, it is the total volume of all carbonators that counts, although it is admitted that the larger carbonators are more convenient for mills of great capacity and are also better adapted for some operations to be performed in them. Generally speaking, the capacity of the carbonators, as well as of any other department in a sugar plant, is determined by the total volume of the carbonators, or any other apparatus, and by the energy of the forces active in the apparatus in question. Let us illustrate this by examples. Of two carbonator stations with the same total volume and with the same heating surface and gas arrangement, the one having hotter steam or gas richer in carbon dioxide has a higher capacity, i. e., it is able to work up more juice, hence more beets, than the other one. Of two filter press departments of the same type and with the same arrangements for inlet and outlet of juice, water and steam, the one having a larger total surface of filtration has a higher working capacity. What is true of the carbonators and filter presses holds good also for other departments. Since the carbonators represent comparatively plain and cheap apparatus, it follows from the above contemplations that a simple way to raise their working capacity is to increase their total volume. This can be done by adding one, two or more carbonators to those already present in the mill, provided there is space enough on the carbonator floor. Better and more practicable in many factories is the increase of the height of the carbonators. This latter means applied by the writer in some factories proved to be always effective and useful. Ordinarily the gas engine is strong enough to overcome the increased pressure of the juice in the carbonators. The latter way is not only cheaper, but also of greater benefit, since it allows a better utilization of the saturation gas which is the more completely absorbed, the longer it is in contact with the alkaline juice, and this is the more the case the higher the carbonators are. This is especially important in factories where the lime kiln and gas engine are not very strong. It also saves a lot of sugar when the space above the juice is large enough, at the same time enabling one to reduce the use of tallow and oil against foaming to a minimum. The question arises how large should the carbonators be and what should be the capacity of the carbonator station per one ton of beets sliced? It is not possible to give a standard measure for all factories, since the necessary carbonator space changes with a number of conditions. Sound, ripe beets give a diffusion juice which is easily defecated and carbonated. Unripe beets or such raised on heavily manured soils cause considerable difficulties at the carbonatation. For this reason the first mentioned beets require less carbonator space. Mills having at their disposal a gas rich in CO_2 need a smaller carbonator space than those having poor gas for saturation and so forth. But let us take actual dimensions of carbonator stations in sugar mills both in the east and in the west. With only one exception, the measurements of the carbonators —as well as of other apparatus given in this publication —were carefully verified and are contained in the following table:

Sugar Factory.	No. 1	No. 2	No. 3	No. 4
Daily capacity	600 tons	475 tons	600 tons	450 tons
Volume of each carbonator	1,006 cu. ft.	841 cu ft.	1,072 cu. ft.	1st carb. 779.5 cu.ft 2d carb. 517.4 cu.ft
Total volume of all (1st and 2nd) carbonators	7,042 cu. ft.	8,410 cu. ft.	8,576 cu. ft.	5,449.7 cu. ft.
Caronator volume per 1 ton beets sliced	11.7 cu. ft.	17.7 cu. ft.	14.3 cu. ft.	12.1 cu. ft.

The height of the carbonators in different, as well as in the same, mills ranged from 12′ to 19′6″. Thus we see that the sizes of the carbonators, as well as the space per each ton of beets cut, differ considerably. But it is worthy of note that while the carbonator space in mill No. 2 was quite liberal, the carbonator departments in the mills Nos. 1 and 4 were among the *weakest* and caused some trouble during the campaign. This indicates that 12 cu. ft. of carbonator space per one ton of beets sliced are hardly sufficient under ordinary circumstances. Considering that raising the height of a carbonator from 12′ to, say, 15′ or 18′ increases its capacity 25 or 50 per cent and that this change can cheaply and easily be accomplished in very many cases, since the heating coils and gas pipes can mostly remain unchanged, it is not too much to say that a sugar factory with a weak carbonator department should not hesitate to make use of this remedy.

FILTER PRESSES.

As far as capacity of the filter presses is concerned it is immaterial whether a mill has, say, eight presses of 900 sq. ft. of filtering surface each, or sixteen presses of 450 sq. ft., etc. And while length and width of the plates and frames usually range from 24 to 40 inches, the dimensions 30″ by 30″ being very common, it is quite natural that a mill with a large daily capacity will prefer presses of larger dimensions for the sake of saving some labor.

With presses of a good type and with proper arrangements for inlet and outlet of steam, juice and water it is only the total surface of filtration that counts. How much surface of filtration is necessary for each ton of beets cut is a question that is rather hard to answer. The surface of filtration needed changes with the quality of the beets, with the care of the work at the stations preceding the presses, with the quality of the filter cloth, etc. The better the beets, the more careful the work at the diffusion battery, at the defecation and carbonation tanks and the better the filtering material, the less surface of filtration is needed, and vice versa. How considerably the surface of filtration changes in various mills can be seen from the following table:

Sugar Factory.	No. 1	No. 2	No. 3	No. 4	
Daily capacity	600	475	600	450	Tons
Surface of filtration of 1st filter presses	4,7[illegible]1	3,500	5,335	1,930	Sq. ft.
Surface of filtration of 2d filter presses	2,365	2,000	2,134	965	Sq. ft.
Surface of filtration of all filter presses	7,036	5,500	7,469	2,895	Sq. ft.
Surface of filtration per each ton of beets cut	11.8	11.6	12.4	6.4	Sq. ft.

It is noteworthy that the factory No. 4 with the smallest surface of filtration has not quite been able to work up 450 tons of beets in 24 hours, and this in spite of a good beet material and fair juices. In the other mills the filter press stations proved to be adequate for the work to be done. It is, then, safe to say that 6 or 7 sq. ft. of surface of filtration per each ton of beets sliced are not sufficient under ordinary conditions.

Since the surface of filtration is given by the number of filter presses and by the number of plates in each press, it is evident that, if the press station is not strong enough in proportion to the other stations, its capacity can be increased either by adding one, two or more presses, if there is space enough, or by increasing the number of plates (and frames) in each of the presses, provided their construction allows to do so. Just to how much the increase of the surface of filtration amounts can easily be calculated in each case.

THE EVAPORATORS.

The multiple effect evaporators belong to the most complicated and most expensive apparatus in a sugar mill. They are, therefore, usually built comparatively strong in proportion to other stations, just as the capacity of the sugar end will mostly be found greater than that of the beet end. However, in factories where the departments of the beet end have been improved and increased for several years it may happen that the evaporators will no longer be adequate for the work to be done. Not intending to discuss the addition of a body proper—which is quite expensive and circumstantial—the capacity of the multiple effect can be increased through a circulator, Pauly's "Saftkocher" (Juice Heater) or by adding a number of heating tubes in each body. The simplest means is perhaps the addition of a so-called circulator representing a very small evaporator heated with live steam and connected with the top and bottom of the first evaporating body proper. Where the front and back plates of the various bodies have not been fully utilized and there is still space for boring new holes, the addition of a number of heating tubes to be put into the new borings will increase their evaporating capacity according to the number of tubes added. The insertion in the multiple effect of the so-called Pauly's "Saftkocher"—a standing evaporator heated with live steam and having in the vapor chamber a pressure up to 15 pounds or about 120° C.—is very effective. This apparatus is used extensively in Germany and is very useful where considerable increase of the capacity of the multiple effect is indispensable and where there is not enough exhaust steam for heating the first effect.

Just how much heating surface is necessary for each ton of beets sliced cannot be answered precisely since it varies with the conditions. All the other things being equal, the heating surface needed is the smaller, the better the beets, the purer the juices, the more carefully the evaporation is conducted, the better the heating tubes transmit the heat and so forth. For instance, heating tubes of copper transmit the heat better than such of brass, and the latter are superior to tubes of iron or steel. Again, the evaporation will be more successful and, hence, require less heating surface, the more completely the condensed water is removed from the heating tubes and the faster the air and gases are removed from the chambers. Some idea as to the heating surface needed may be gained from the following table:

Sugar Factory.	No. 1	No. 2	No. 4	No. 5	
Daily capacity.	600	475	450	450	tons
Type	Quintuple effect	Quadruple effect	Quadruple effect	Quadruple effect with Circulator.	
Heating surface of all effects	19,438	14,067	10,783	10,000	sq. ft.
Heating surface per 1 ton beets sliced	32.4	29.6	24.0	22.2	sq. ft.

As a matter of fact, the mill No. 5 could not successfully evaporate the juice with the heating surface available and had to add a circulator to somewhat increase the capacity of the multiple effect. On the other hand the heating surface in the mill No. 1 was quite strong so that the heating tubes were not covered with juice for a number of days during the campaign. The heating surface needed lies, then, between these two extremes.

If the increase of the heating surface by the means recommended is not possible, say, for lack of space or not desirable for whatever reason, the following remedies will prove quite effective: the use of *hotter* steam in the first body and keeping the juice stand in all bodies as low as possible. If the exhaust steam heating the first body has, e. g., 5 pounds pressure, then an increase of its pressure up to 8 or 10 pounds will essentially increase the capacity of the multiple effect. Because, other things being equal, the *juice evaporates the faster, the greater is the Temperaturgefälle,* i. e., the difference in temperature between the heating steam and the evaporating juice. It is admitted, however, that in this latter case, by virtue of the higher back pressure the work of the engines will not be as economical as it would with lower pressure of the exhaust steam.

Keeping the level of the juice in the bodies low, materially increases their evaporating capacity, although this plain and always applicable means is very often neglected in sugar factories. The effectiveness of this remedy will be better comprehended by remembering that the boiling point is the lower the smaller the height of the juice in the effects, in which case the "Temperaturgefälle" (change in gradient) will be greatest, which, as we have seen, means faster evaporation.

It is hardly necessary to mention the fact that heating tubes free of scale do more effective work. In order to remove the scale some factories boil out the evaporators first with muriatic acid and then with soda, others perform these operations in the reversed order. Which is right? The scale in the evaporators consists of lime in combination with carbon dioxide, organic acids, sulphuric acid, etc. The muriatic acid as it is used for the evaporators—not more than half per cent strength—is able to completely dissolve or to destroy the carbonate of lime only. It is, therefore, better to boil out the evaporators first with soda which converts all the salts named into carbonate of lime, and then to boil out with muriatic acid. Boiling out with bisulphate alone renders also good services.

THE VACUUM PANS.

For regular work in a sugar mill it is necessary to have at least one vacuum pan for boiling the first meladas and another pan for the second massecuites. A modern vacuum pan is so expensive and usually constructed in such considerable sizes that the addition of one more pan is not often practiced. Usually they are built of such dimensions and with such heating surface as to be fully adequate for the work required.

What was said of the evaporators with regard to steam and material of the heating tubes holds also good for the vacuum pans. Copper and brass coils transmit the heat better than those of steel and iron. And while high and low pressure steam have practically the same amount of heat they differ considerably in temperature. In-as-much as the higher temperature of the heating steam increases the "Temperaturgefälle" and, hence the speed with which the water of the thick liquor can be evaporated, the application of high pressure steam in the vacuum pan means an increase of its capacity. Another although indirect means to make the pans adequate for the work in case of emergency is to evaporate the juices in the multiple effect to a high *Brix,* say to from 60 to 70° Bx. On the other hand, if the vacuum pan is stronger in proportion than the evaporators, then the thick juice from the last body may be pumped out as soon as it has about 50° Bx. A part of the evaporation will be then done in the vacuum pan, although the fact must be taken into consideration that the evaporation in the vacuum pan means higher coal consumption, since the live steam is utilized in the pan only once, whereas in the multiple effect the steam is utilized four or five times. Careful steaming out of the pan after each strike keeps the heating coils clean whereby the transmission of the heat through the coils is kept at its maximum. A good experienced sugar boiler knows how to appreciate these means.

However, once in awhile during the campaign it happens that the meladas in the pan "do not boil." As a consequence the whole mill is "up against the pan" and the capacity is thus impaired It is usually the case either at the start of the campaign when unripe beets are worked or at the end of the campaign when a part of the sliced beets are spoiled. The difficult boiling of the thick liquors from such beets is caused primarily through pectin substances and lime salts combined with organic acids. As soon as difficult boiling has been noticed, it will be found useful—in addition to careful extraction, defecation and carbonatation—to treat the thin juice with sal soda, converting those lime salts into carbonate of lime which is filtered out. The juices so treated boil then much better, especially when the alkalinity of the thick liquor is kept low, not above 0.01.

That dry or overheated steam should never be used for heating purposes at the vacuum pans or elsewhere, since it is a poor conductor of heat, we wish here to mention for the reason that such steam is sometimes wrongly applied in the vacuum pans and other stations.

THE CENTRIFUGAL MACHINES.

As far as the centrifugals are concerned, their capacity increases with their radius, with the quantity of the spinning massecuite and with the square of the number of revolutions they make in a minute, no matter whether they are driven by water, steam or electricity. From the above it follows that the velocity has considerable influence upon the capacity of a machine and it makes quite a difference whether a centrifugal makes 1,000 or 1,200 revolutions in a minute. A simple calculation shows that, all the other conditions being equal, 10 machines making 1,200 revolutions are able to work up as much massecuite as 14 machines running with a speed of 1,000 revolutions in a minute. While it is not possible in the practice to keep a centrifugal running all the time with a speed of 1,200 revolutions, the above data suggests that care should be taken to keep the speed of the centrifugals as near to the upper limit as possible. Sliding of the belts has here considerable bearing.

The machines mostly used in the sugar factories in this country are Weston centrifugals of 30, 36 and 40-inch diameter, although the 40-inch machines of the belt-driven type are usually preferred to the other types and sizes. The number of centrifugals necessary for each factory somewhat changes with quality and temperature of the meladas to be spun, with the amount of syrup or water added to the mixers, and so forth. Usually one 40-inch machine is able to spin the meladas obtained from 50 to 60 tons of beets, hence ten such machines are needed for a mill having a daily capacity of from 500 to 600 tons of beets. Factories of this capacity have either 5 centrifugals for first meladas and 5 for second meladas, or 6 machines for firsts and 4 for seconds, although the reverse is the scheme to be preferred, namely 6 machines for second (and third) massecuites and 4 for white massecuites. With the number of machines their size and speed given, their capacity is then properly speaking, fixed. We should like, however, to call attention to one remedy which improves the work of the centrifugals and one that was used by the writer in a number of factories with success. It is the application of steam between jacket and basket, especially for second and third fillmasses. A small steam pipe of, say, half-inch diameter with small openings directed against the basket, keeps the melada warm, the molasses contained in the melada in a less viscous state. That way the molasses is more easily separated from the crystals so that the time of spinning can be reduced. If the steam is free of water or is made dry by directing it against a piece of flat iron (inserted between jacket and basket) and not directly against the basket, then the dissolution of sugar by the steam is practically out of the question: it is not the water, it is the heat of the steam that is needed here.

SUGAR EXTRACTION.

It goes without saying that sugar is produced in the beets while they are still in the soil. As soon as they have been dug out, sugar losses are liable to occur through decomposition of the sucrose. The fact that siloed beets often show a higher sugar content than the corresponding fresh beets does not stand in any contradiction to the above statement. It is only the sugar percentage that has increased, *absolutely* the sugar decreases in siloed beets as it does in beets under other conditions, when out of the soil. In other words, the weight of the siloed beets multiplied by their average sugar percentage gives a figure smaller than the one obtained through multiplication of the weight of the fresh beets by their sugar content. The problem of the sugar factory is, then, merely to extract the sugar from the beets as completely as possible, carefully avoiding any unnecessary sugar losses. While the *diffusion battery* is the department where the sugar extraction takes place, the other stations commencing with the carbonators down to the vacuum pan have as their object the purification, filtration and evaporation of the raw juices obtained in the diffusion battery. Inasmuch as the purification of the juices materially increases the yield of sugar, it is convenient to deal at the same time with both sugar extraction and epuration. As far as sugar extraction in the diffusion battery is concerned it depends upon four conditions: temperature, state of the chips, percentage of draw and duration of the extraction. While the cells in a long battery with, say, 14 diffusors are emptied every 5 to 7 minutes, the change of the cells in a short battery with about 8 large cells takes place at greater intervals, namely in 10 to 12 minutes. With the number of cells given in a battery, whatever its type, it would not be wise to prolong the time of extraction in order to better exhaust the cossettes, since in this case the capacity of the battery would be impaired. Only in one case, namely when the battery is stronger than the other stations, can the extraction take place somewhat slower for the purpose of obtaining a better yield of sugar.

Of the other means, the "draw," or the percentage of juice to be drawn from a cell, is the most expensive and least economical one, since larger draw means higher coal expenses, more work in the carbonators, filter presses and evaporators, hence decrease of the capacity of the mill. We most emphatically wish to lay stress upon all those disadvantages in view of the fact that in many sugar factories the people like to make frequent use of this means and to regulate the sugar content of the pulp by the draw rather than by temperature and size of the chips, simply because it is so much more convenient to do so than to strictly observe the temperature in the heaters or to take care that the slicers should give the right kind of cuttings. While the draft can change within 100 to 120 per cent and more, calculated on the weight of the beets, it should be borne in mind that a minimum of draw corresponds to the highest economy in work. At the beginning of the campaign careful observations must be made so as to find out the percentage of draft that is most economical for both sugar extraction and capacity of the mill. Once stated, the draw ought to be kept so for a while, and should not be changed often as is practiced in some factories. Uniform work in the diffusion battery, as well as throughout the mill, should be the underlying principle. When raw juice of uniform concentration is pumped into the measuring tanks, the carbonator man knows what he will get into his carbonators. As a consequence the operations of heating, treating with lime and gas can be performed more intelligently and uniformly.

The regulation of the temperature in a battery is a very effective way to accomplish a good extraction of the sugar from the beets. With ripe, sound beets the temperature in the battery can be kept as high as 80° C. and even two or three degrees higher. When it is not possible to exhaust the cossettes far enough with this temperature, it is advisable to keep two or three more cells hot rather than to raise still farther the above mentioned temperature which would render the chips soft and thus impair the circulation in the battery.

The most economic and prudent means to achieve a satisfactory sugar extraction will always be found in good chips. It is perfectly true that this means requires more care than the others, especially at the start of the campaign. But once well organized, it does not require appreciably more time and expenses to obtain good chips than it takes to get poor ones. In order to get as complete an extraction as possible the chips should be fine enough and above all uniform. While the thickness of the chips usually ranges from two to three or four millimeters and while it is naturally easier to exhaust finer cuttings than thicker ones, their fineness is limited by the fact that too fine chips retard the circulation in the battery. For this reason the chips must necessarily be the thicker, the larger the cells. Uniform cuttings, however, are always useful. They can and should be applied in batteries of any type, for the following reason: When the cells contain cuttings of two different sizes, the thinner cuttings will be sooner exhausted than the thicker ones. There remains, then, the dilemma either to dump the pulp with a comparatively high average sugar content, or to continue the diffusion in which case a considerable portion of non-sugars will be extracted from the thin chips. Consequently, it is only with uniform chips that a good exhaustion of their sugar and at the same time a purer raw juice can be obtained. A few rules enable one to get good, uniform cuttings:

1. The same type of blocks and knives, at least for a certain period, ought to be used.

2. The knives should be sharp, and put into the blocks as uniformly as possible, and—what is essential—the distance between knife and "Vorlage" (Receiver) as well as the height of the knives above the "Vorlage" (Receiver) must be in all blocks the *same*.

3. The funnel above the slicing machine should be full to the top, and never less than two-thirds full, the beet elevator is to be regulated accordingly. In case the funnel does not contain enough beets so that there is not sufficient weight on the slicer, the beets slip on the knives and as a consequence mash is formed instead of regular chips.

4. Good chips are not supposed to contain the so-called "hands," or at least the latter should be limited to a minimum. Such hands are usually formed when ribs in the knives are broken. Such knives ought to be replaced by good ones without delay.

5. As soon as the knives have been damaged through stones, bolts or equally hard objects, the cutter must be stopped immediately, the damaged knives taken out and replaced by new ones.

6. If the knives do not give satisfactory chips on account of being plugged up through straw, grass, etc., the foreign matter should be removed, e. g. by means of the pointed ends of old files, after which the same knives can be used again. This latter operation should be performed each time after the slicer has cut beets for two or three cells. When there are two cutting machines, —which is the case with the modern sugar factories—care should be taken that while the one machine is cutting beets, the other one should be cleaned, provided with good, sharp knives, etc., and brought into action as soon as the chips coming from the first machine are no longer satisfactory.

Hardly any factory will endeavor to exhaust the pulp beyond 0.25 per cent of sugar, which is neither economical nor easy to accomplish. An average sugar percentage of 0.3 to 0.4 can be considered as fair work.

Since the chemical *purification* of the raw juice is perhaps the most important of all operations in a sugar factory, it may be worth while to treat it here somewhat more rigorously than the other processes. This is all the more justified that in the textbooks dealing with sugar manufacture we usually find that so and so much lime and certain temperatures are to be applied in the carbonators, but no adequate explanation of the chemical phenomena involved is given.

The chemical epuration of the diffusion juice is performed mainly by means of lime and heat and has the following effects:

1. Neutralization of the acids and acid salts naturally occurring in the beets. The neutralization is primarily necessary to prevent inversion of sucrose.

2. Precipitation of some non-sugars, like the acids: carbonic, phosphoric, oxalic, malic and others.

3. Coagulation of proteins, due to the heat applied in the carbonators.

4. Removal of coloring matter.

5. Removal of ammonia from some non-sugars, e. g. from asparagine and glutamine. For instance,

$$\underset{\text{Asparagine}}{COOH.\ NH_2.\ CH.\ CH_2.\ CONH_2.} + \underset{\text{Water}}{H_2O} =$$
$$\underset{\text{Aspartic acid}}{COOH.\ NH_2.\ CH.\ CH_2.\ COOH} + \underset{\text{Ammonia.}}{NH_3.}$$

6. Mechanical precipitation of suspended foreign matter.

7. Sterilization of the juice for protection against the action of microörganisms and germs.

That the chemically purified juice is more easily filtered, evaporated and worked generally speaking, is too well known to be treated here. What temperature and how much lime should be used in the carbonators? The answer to this question we can give by considering the purposes they have to accomplish. A good many proteins coagulate only at a temperature of 85° C.; the coloring substances combine partly with the proteins; ammonia is the more removed from the organic nitrogenous bodies (from asparagine, etc.), the higher the temperature which is also favorable for enveloping the foreign matter. On the other hand it is very hard, if at all possible, to boil the treated juices in the first carbonators.

So that the above data point to the necessity of keeping the temperature in the carbonators at from 85 to 100° C. In the first carbonators which react violently when very hot, the juice should be heated to from 85 to 90° C. after the saturation has taken place at 75 to 85° C. In the second carbonators, however, the treated juice can be heated up to 95 or 100° C.

It may be mentioned here that large carbonators are preferable to small ones inasmuch as it takes more time to heat up the juice and treat it with gas. As a consequence there is more time and hence better chance for the performance of the processes of coagulation (proteins), precipitation (lime salts), destruction of non-sugars (amides, amino acids, etc.), enveloping of the foreign matter—advantages that are not to be underestimated.

If lime were to be used only for neutralization of the acids, then the amount to be applied would be exceedingly small. Sound beets contain a juice 10cc of which can be neutralized with 3 to about 7cc of "factory alkali," the strength of which corresponds to the strength of "factory acid." This means that 0.05 per cent of lime are sufficient to neutralize the acids in the diffusion juice. The amount of lime needed to precipitate some non-sugars, as lime salts and to destroy other non-sugars is probably just as much or a trifle more. However, 0.1 to 0.2 per cent lime added to the diffusion juice does not give a full defecation of the juice which in addition filters very slowly. The least amount of lime necessary to get juice which is easily filtered, is about 1½ per cent. An amount of 2 to 2½ per cent of lime calculated on the weight of the beets is certainly sufficient in all cases. Factories using for sound beets above this percentage are simply wasting lime, to say nothing of other disadvantages.

In this connection we should like to call attention to the fact that it is useful to run acidity determinations of the diffusion juice, most conveniently by means of an alkali which we propose to call "factory alkali," since 1cc of it neutralizes 1cc of factory acid. The diffusion juice is for these titrations to be diluted with distilled water. And yet, strange as it is, there is hardly a sugar factory in this country requiring of the chemists to regularly determine the acidity of the raw juice. The addition in the beet end sheets of the column: "Acidity of diffusion juice" would not appreciably burden the laboratory work. The writer's observations convinced him that as long as the acidity runs from 0.03 to 0.06 or 0.07 the beets are sound. A further rise of the acidity to say, 0.10 and above, is a sure sign that some rotten beets are coming into the factory. It is then, and only then, that application of more than 2½ per cent of lime would be advisable.

When the juice in the carbonators foams heavily and the carbonators are not large enough, there is loss of juice through the big vapor pipes of the carbonators. Such juice can be saved by constructing on the roof at the highest points of those pipes a somewhat inclined wooden trough fitted inside with galvanized iron. The upper ends of the vapor pipes fitted into the bottom of the trough are on the same level with this bottom. A small pipe with valve from the lowest point of the trough will bring the overboiling juice back to any station of the mill, most conveniently to the carbonators. Such a trough costs twenty or thirty dollars or so, and saves lots of sugar.

As the sugar remaining in the *press cakes* represents a considerable item among the losses that are unavoidable in the sugar manufacturing process, it is but natural that the filter press station requires considerable attention. In the first place, good diffusion juice, carefully treated in the carbonators with properly burned lime from high-grade lime stone, gives always a saturation juice that is easily filtered and sweetened out. That before coming into the presses, the juice must pass through an adequate stone catcher, we wish only to mention. The cardinal point to be emphasized here is that the formation of the lime cakes in the presses as well as the sweetening out with water should take place as uniformly as possible. This can be achieved in such a way that the juice from the carbonators is forced not directly into the presses but into a reservoir placed high enough above the presses from which reservoir the juice runs through natural gravity into the filter presses. The pressure being always practically equal, the cakes formed are of uniform size. Again, the water used for sweetening out the cakes should also be pumped into a tank above the presses to have a uniform water pressure in the filter presses. If, however, a pump is used for forcing the water into the presses, then stress is to be laid upon starting the pump at the outset as gently as possible. That way the water finds its way along all the channels formed in the cakes, uniformly penetrating them. And as soon as the water appears from the cocks, the pump may be run faster. How much water is to be used has to be found out at the start of the campaign through analysis of the lime cakes. Their continuous chemical control as to their sugar content will then be a sure guide for the filter press foreman. If in spite of all the care in the presses, the cakes show a high sugar percentage, it is reasonable to assume that the cakes contain sugar in chemical combination with lime, i. e., as saccharate. This should without delay be stated by running two sugar determinations of the cake: the usual one by means of acetic acid or ammonium nitrate will give the total sugar percentage, and the other method consisting simply in extracting the cake with water will give the sugar mechanically contained in the cake as juice. The result of this second determination subtracted from the first one gives the percentage of sugar in the shape of saccharates. If the percentage of the saccharates is considerable, the work in the carbonators must be changed so as to decompose the saccharates into sugar and lime. A sugar content of one per cent in the cakes of the first presses can be considered as fairly good work, the cakes of the second presses usually contain very little sugar, often none.

Concerning the cakes in the thick liquor presses as well as the slime in mechanical filters we wish to remind that their throwing away into the sewer—which is practiced in some factories—is a waste which has no justification whatever, remembering that the cakes in the thick juice presses have as much as 30 per cent of sugar. Arrangements should be made to return them into the carbonators.

The other stations we may overlook here, all the more since the recovery of sugar from fillmasses, syrups and molasses has been treated by the writer in another series of articles in the columns of the American Sugar Industry and Beet Sugar Gazette. (See: "Recovery of Sugar from Syrups and Molasses," this Journal, Nos. 14, 15, 16 and 17, 1905.)

Calculations in a sugar factory afford the best means to get a real picture of how the work is going on in the mill at any moment. However, such calculations must not be complicated and should not require much time which is very precious during the campaign. Formulas, no matter how accurate the figures they give, are not understood by everybody and not liked by many. In the following we give a rule (or rules) by which the calculations are simplified without the necessity of using formulas:

"When the amount of water in a sugar solution (or product) is increased or decreased, then the Brix is reversely proportional to the total weight of the sugar solution (or product)."

We can express this rule also in the following way:

"When the amount of solids in a sugar solution is increased or decreased, then the water content is reversely proportional to the total weight of the sugar solution."

By sugar solution is meant here: Thin juice, thick liquor, fillmass, syrup, molasses, melted sugar, or any other sugar product. For practical calculations, Brix can be considered as designating the solids in a sugar solution.

The reverse, also, holds good:

"When the Brix (solids) is changed in a sugar solution, then the total weight of the sugar solution is reversely proportional to its water content."

This plain rule (or rules) is capable of being applied for the solution of many sugar problems. Its usefulness is augmented by the fact that it is applicable not only for sugar solutions, but also for pulp, lime cake, etc.

Let us illustrate the general applicability of the above rule by a few examples.

Problem 1. Thin juice of 12 degrees Brix, after passing the evaporators, gives a thick liquor of 65° Brix. What is the quantity of thick liquor obtained and how much water has been evaporated in the multiple effect?

The amount of thick liquor is smaller than that of the thin liquor and can, according to our rule, be expressed by the ratio $\frac{12}{65}$, or $\frac{12}{65} \times 100 = 18.5$ per cent of the thin juice. The quantity of water evaporated equals 100 —

$18.5 = 81.5$ per cent of the thin juice. Knowing that a sugar mill obtains about 125 per cent thin juice (for instance, a mill of 600 tons capacity gets $600 \times \frac{125}{100} =$ 750 tons thin juice), we are enabled through the solution of this problem to judge the work to be done by the thick liquor pump, or to find out the total volume the thick liquor tanks on the pan floor must have in order to hold the thick juice for the vacuum pan.

Problem 2. Thick juice of 65 degrees Brix is boiled down in the vacuum pan to 92 degrees Brix. To find the quantity of massecuite obtained and the amount of water evaporated in the pan.

The amount of massecuite is, in accordance with the above rule, given by the ratio $\frac{65}{92}$, which equals $\frac{65}{92} \times 100$ $= 70.6$ per cent of the weight of the thick liquor. Hence, $100 - 70.6 = 29.4$ per cent of the weight of the thick liquor is the quantity of water evaporated in the pan.

The Problems 1 and 2 enable us also to find the amount of massecuite expressed in percentage of the weight of the beets. Namely, let us take a mill of 800 tons capacity. It gets:

$$800 \times \frac{125}{100} = 1{,}000 \text{ tons thin juice in 24 hours.}$$

$$1{,}000 \times \frac{18.5}{100} = 185 \text{ tons thick juice in 24 hours.}$$

$$185 \times \frac{70.6}{100} = 130.61 \text{ tons massecuite in 24 hours.}$$

$185 - 130.61 = 54.39$ tons of water were evaporated in the pan. It may be mentioned here that the amount of massecuite actually obtained is somewhat smaller on account of unavoidable mechanical losses as well as because of the removal of some non-sugars. Through solution of Problem 2 we are also able to find the volume of the mixer needed to hold the first massecuite.

Problem 3. Thin juice from the first effect of 15 degrees Brix and dry yellow sugar were simultaneously allowed to run into the melter until it was nearly full. The melted sugar showed 60 degrees Brix. How much yellow sugar was added?

The thin juice, the amount of which may be designated with 100 per cent, had 15 degrees Brix, hence 85 per cent water, the melted sugar showed 60 degrees Brix, hence 40 per cent water. The total amount of melted sugar obtained is more than the thin juice alone, and is, in accordance with our rule, given by the ratio $\frac{85}{40}$, which equals $\frac{85}{40} \times 100 = 212.5$ per cent of the weight of the thin juice. Consequently, the amount of yellow sugar added is $212.5 - 100.0 = 112.5$ per cent of the weight of the thin juice. Knowing volume of melter and Brix of melted sugar we can readily find the total weight of the melted sugar, which is, say, 70,000 lbs. The amount of yellow sugar added is then: $70{,}000 \times \frac{112.5}{212.5} = 37{,}059$ lbs.

Problem 4. Pulp, coming from the diffusion battery and showing 95 per cent water, was passed through a Bergreen's press when it showed 87 per cent water. What is the amount of pressed pulp obtained?

The fresh pulp has 95 per cent water, hence 5 per cent dry substance, the pressed pulp has 87 per cent water, hence 13 per cent dry matter. The amount of pressed pulp is evidently smaller than the quantity of fresh pulp, and is, according to the above rule, given by the ratio $\frac{5}{13}$. This expressed in percentage gives $\frac{5}{13} \times 100 = 38.5$ per cent, i. e., every 100 tons of fresh pulp furnish 38.5 tons of pressed pulp under the given conditions. The amount of water pressed out equals $100 - 38.5 = 61.5$ tons per 100 tons of fresh pulp. (The small amount of solids contained in the water which is pressed out is not taken here into consideration.)

Problem 5. Pressed pulp with 13 per cent dry matter, after passing the pulp drier, showed 88 dry matter. How much dried pulp was obtained and how much water was evaporated in the drying plant?

In accordance with the above given rule, the amount of dried pulp is expressed by the ratio $\frac{13}{88}$, which equals $\frac{13}{88} \times 100 = 14.8$ per cent calculated on the weight of the pressed pulp, or $14.8 \times \frac{38.5}{100} = 5.7$ per cent of the fresh pulp. The amount of water evaporated equals $100 - 14.8 = 85.2$ per cent; i. e., 85.2 tons of water have been evaporated from every 100 tons of pressed pulp. The Problems 4 and 5 enable us, then, to find the percentage of pulp obtainable under whatever conditions, as well as to calculate the amount of coal consumed in the pulp drier as soon as we know the calories of the coal which can be reckoned from the results of an elementary analysis.

Problem 6. Molasses (syrup from the second melada) of 78 Brix was added to pulp in the process of manufacturing dried beet pulp. What percentage of the feed is obtained from 1 ton of the molasses, the feed having 85 dry matter, and how much water loses the molasses in the drying plant?

The molasses when entering into the composition of the pulp molasses loses a certain percentage of water, since from 78 dry substance it is dried in the drying plant up to 85 dry substance. According to the above rule, the amount of obtainable feed is given by the ratio $\frac{78}{85}$, which is equal to $\frac{78}{85} \times 100 = 91.8$ per cent of the molasses. In other words, 100 tons of molasses furnish 91.8 tons in the shape of the feed. The amount of water to be evaporated in the drying plant is $100 - 91.8 = 8.2$ tons per 100 tons of molasses.

The solution of the problems, 5 and 6, gave us the following figures:

100 tons of pressed pulp furnish 14.8 tons of dried feed.

100 tons of pressed pulp must lose 85.2 tons water to make dried feed.

100 tons molasses furnish 91.8 tons of dried feed.

100 tons molasses must lose 8.2 tons water to make the dried feed.

These figures simply show how economical and profitable it is to add molasses to the pulp and to manufacture dried pulp-molasses instead of dried pulp alone. No beet sugar factory having a pulp drier should hesitate to do so. The dried molasses beet pulp is a feed eagerly eaten by cattle, sheep, etc., is highly appreciated by stockmen, and finds a ready market. The arrangement necessary for the production of the pulp-molasses is very simple. All that is needed is one tank, or better, two tanks, for regular work, placed above the worm conveying the pulp from the presses to the pulp drier. From the bottom of those tanks, into which molasses is alternately pumped, a small pipe of, say, 1½-inch diameter, runs to the pulp conveyor and ends a few inches above it. A valve in the pipe enables one to regulate the flow of the somewhat heated molasses to the pulp.

How much molasses should be added to the pulp?

This depends upon the conditions existing in the sugar factory. When a part of the molasses is to be used for purposes other than for manufacturing pulp-molasses, then less molasses is to be added, otherwise more. In accordance with these different conditions the addition of molasses to the pulp can be regulated at will in such a manner that the resulting molasses beet pulp may have a sugar percentage ranging from 15 to 35 per cent.

Problem 7. A beet sugar company sold its molasses to a sugar refining company (or any other party) with the condition that the molasses should not have any less than 40 Beaumé = 73.7 degrees Brix. The molasses actually obtained in the factory ranged from 76 to 82 degrees Brix. How much water is to be added in order to get molasses of 73.7 Brix?

Through the addition of water to the molasses we shall get a total amount of molasses larger than the quantity of the undiluted molasses. According to our rule the diluted molasses is given by the ratio $\frac{76}{73.7}$, or $\frac{82}{73.7}$. Expressed in percentage we get $\frac{76}{73.7} \times 100 = 103.1$ per cent, or $\frac{82}{73.7} \times 100 = 111.3$ per cent. In other words, to every 100 tons of molasses of 76 or 82 Brix we have to add 3.1 tons, or 11.3 tons of water respectively.

In connection with Problem 7 it may not be out of place to tell here the following case: The German Beet Sugar Company, Osterwieck am Harz, in accordance with a contract, had to deliver molasses of not less than 40 degrees Beaumé to the Sugar Refining Company Frellstedt. The molasses—running syrup from the second massecuite—actually obtained in the beet sugar factory had on the average about 79 degrees Brix and was for a campaign or more delivered with that density. Since the purity does not change whether the molasses contain more or less water, the factory management decided, upon our recommendation, to dilute the molasses with water so as to make its specific gravity about 73.7 degrees Brix. In that way both parties concerned got exactly what they had to have, according to the contract. Since on the average to every 100 tons of molasses $\frac{3.1 + 11.3}{2} = 7.2$ tons of water could be added, it is readily seen that with the new arrangement the sugar factory at Osterwieck was able to get during a campaign quite a few carloads of molasses more than it used to get previously.

Too much space would be needed to enumerate all the problems which can easily be solved by the above given rule. Those given are sufficient to illustrate its wide applicability. Equally, we are not able to discuss here the process of continuous diffusion, continuous saturation and others, for lack of time. A good many more interesting topics had to be left out for the same reasons.

Nor could we, in speaking of capacity, or sugar extraction, go into details which can usually be found in textbooks on sugar manufacture. Our purpose was to touch merely upon the most important problems or to deal with such questions which are not mentioned or not adequately treated in textbooks.

The personal ability of the factory managers, superintendents and their assistants is by no means denied. The care taken to guard against the stoppage and breakage of machinery, or that sliding of belts should be eliminated or reduced to a minimum, is of importance, for it is self-evident that all apparatus should be in the best possible condition to insure good results. Equally important is an adequate technical force to meet any emergency. The right kind of men at the various stations of a mill and a well-pondered organization of the whole work to be performed daily and hourly during the campaign are unquestionably of great significance. But a superintendent, however skilled and experienced, cannot make a pump, having the capacity of 5 hectoliters per minute, do the work of a pump of 6 hectoliters' capacity during the campaign, nor can he extract 14.1 per cent of sugar (including the losses) from beets with a sugar content of but 14. His competence consists largely in his knowledge of conditions and discriminating power to judge what he can accomplish and what he cannot. His ability is fully demonstrated by bringing the full capacity of a mill into play and by extracting the maximum percentage of sugar in a most economical way. The means to achieve all these purposes we have tried to outline in this publication.

In conclusion we should like to say that the American farmer, who is sending abroad many millions worth of cotton, grain, fruits and meat, can and should raise sugar beets for the production of the sugar consumed by the nation. He can raise even beets superior to those of any other country, as far as quality is concerned. A good deal has been accomplished. The sugar factories constructed by American construction companies are in a good many respects superior to those built in Europe. Sugar content and purity of beets grown in this country, especially in Colorado and California, are very high, often a great deal higher, than can usually be found in the

Old world. Beets with a sugar percentage of from 17 to 20 per cent can be found in those states in whole carloads. Often the beets run as high as 20 to 25 per cent. Nor is this the limit. Thorough and careful selection of mother beets, application of thoroughly scientific, rational methods in plowing, cultivating, thinning, etc., will render it possible to develop in time a still higher type of beets.

There is still one great problem confronting the American farmer. Germany has produced on the average for the last three years three tons of beets to the acre more than the United States. The smaller tonnage means a loss to the American farmer in the net profit of about from ten to fifteen dollars per acre. Taking into consideration the generally superior conditions in the United States it surprises one that the farmer in this country does not get a tonnage even larger than in Germany. As we have seen from the first part of this paper the essential things that are necessary for the achievement of that object consist in use of the best possible beet seed, in judicious application of the right amount and kind of fertilizers and manures at the right time and in employment of intensive, prudent methods in all the tillage operations, commencing from fall plowing up to the time when the beets are to be dug out.

The labor question! True, this is a weak point, but the only one. And even this question can be solved in a satisfactory manner, since it is in the power of this nation to get as much labor as is needed through a wisely regulated immigration system. The labor saving devices, for instance, steam plows, beet seeders, beet toppers, etc., invented and already applied in beet culture, will cut down manual labor more and more. The single-germ beet seed, in connection with which the work done at the United States Department of Agriculture is very valuable, will also facilitate the labor question, inasmuch as the thinning of beets—one of the hardest operations—will be essentially simplified and cheapened.

What we still need in this country is an adequate sugar literature. The weekly and monthly sugar journals published in Germany rank, no doubt, with the best scientific and technical periodicals of Europe. The same is true of the textbooks and special publications relating to the sugar industry. The sugar institute in Berlin under the direction of Professor A. Herzfeld is the greatest of its kind in the world. It is such kind of journals and institutions that have been in a large measure instrumental in creating in that country the world's greatest beet sugar industry. If the people in this country are in earnest to bring into life a sugar industry commensurate to the other leading industries, they must not forget that the creation of a strictly *American* sugar literature is for that purpose quite essential. Is there anyone who can deny the great importance of standard books covering the most momentous problems with which those connected with the sugar industry are confronted? Yet, we have very few, if any, special books dealing with the sugar problems viewed from the standpoint of strictly *American* conditions. This is, it is needless to say, of far greater interest and import than translations of even the best foreign publications. For instance, a book dealing in a clear manner with the most useful and necessary calculations throughout a modern American sugar factory, one showing in a plain but exact way how the capacity of each station can be calculated, containing a few chosen chapters with regard to fuel economy, utilization of by-products, crystallization in motion and illustrating the text with numerous examples from the sugar factory, ought to be, it seems to us, of interest to sugar manufacturers, managers, superintendents, chemists, mechanics and all their assistants.

When we take into consideration that the increase in population through natural augmentation and immigration is more than a million and a half per annum; when we further consider that the population in the United States will be in twenty years 120 millions, in fifty years from today about 200 millions, we must admit that the time is very close when intensive agricultural methods will have to be applied, anyway. The sugar beet has proved to be an excellent educational means for the European farmer, and with that vegetable more intensive modes have been successfully introduced in general farming. Is it, further, not quite natural that this Republic, being the greatest sugar consumer in the world, ought to be also the world's greatest sugar producer? All the conditions for such a great industry are present here. There is a great abundance of available fertile land for the beet, there is plenty of sunshine and water, abundance of capital, an energetic, industrious and intelligent population in addition to market facilities, and already considerable experience in both beet raising and sugar manufacturing.

Appendix.

Editor's Note.—The utilization of the by-products of beet sugar factories is, during recent years, forcing itself upon the attention of all who are interested in the development of the American beet sugar industry, and it has occurred to the publishers, therefore, to add something upon this subject to the work by Dr. Jodidi, who has not touched upon this matter in the preceding pages. The following, by Dr. C. O. Townsend, reprinted in THE AMERICAN SUGAR INDUSTRY AND BEET SUGAR GAZETTE, from the Year Book of the Department of Agriculture for 1908, contains valuable information relative to the utilization of by-products:

INTRODUCTION.

The primary object in growing sugar beets is the production of refined sugar. Any other materials, therefore, that remain or are produced in the manufacture of refined sugar from beets should be classed as by-products. These consist chiefly of beet tops (leaves and crowns), pulp, waste molasses, and lime cake. From these original by-products other by-products are often made that are of much greater commercial value than are the original by-products; for example, alcohol made from waste molasses and commercial fertilizer made from refuse slop. The first mill for the utilization of sugar beets, built more than one hundred years ago, made alcohol as one of the chief products, while sugar was looked upon as a by-product or at least as a product of secondary importance. In recent years both the quantity and the quality of sugar produced from beets have placed the material in the highest rank as a commercial product. The total quantity of sugar produced annually from beets is approximately the same as that produced from cane, whether considered from the standpoint of sugar production in the United States or from the standpoint of the world's output, and the sugar is just as satisfactory for all purposes, including the preparation of jellies, jams, and preserves, so far as the Department of Agriculture and several of the state experiment stations have been able to determine.

A careful consideration of the present uses in general of the by-products of the sugar beet brings one to the conclusion that much of their real value is being lost to the farmer and to the sugar company. This paper is written with the hope that a more general interest may be taken in the proper utilization of the sugar beet, and especially of the by-products.

TOPS.

The first by-product of the sugar beet is the tops, composed of leaves and crowns, which are removed by the grower in preparing the beets for the factory at harvest time. Although the sugar is made in the leaves, only a small percentage remains in them, as it is constantly passing into the root, where it is stored. The crown also contains a comparatively small quantity of sugar, while both leaves and crowns contain a comparatively high percentage of mineral matter, or ash. The percentage of ash in the leaves is usually about three times as great as the percentage in the untopped beet, while the percentage of ash in the crown is more than six times as great as the percentage in the whole beet. On account of the low sugar content and the high percentage of ash in the leaves and crowns they are discarded so far as sugar making is concerned, and therefore become a secondary product or by-product.

The leaves and crowns may be utilized either as a fertilizer or as a stock food. As a fertilizer they may be plowed under in the fall while still green or they may remain on the ground and be plowed under in the spring after more or less decomposition has taken place, or when fed to stock they may enter into and form a part of the stable manure, and in this manner be returned to the soil. If left in the field and plowed under, they will add a small amount of humus to the soil and a comparatively large amount of mineral matter. They should therefore be spread over the ground as uniformly as possible if they are to be plowed under.

The weight of leaves and crowns produced per acre varies greatly in different parts of the country, as well as from season to season, depending upon soil and climatic conditions. An average of 4 tons of tops per acre is a conservative estimate. This means an annual yield of about 1½ million tons of this by-product. Of this quantity about one-fourth, or 1 ton per acre, is crowns and the remaining 3 tons per acre are leaves. The crowns contain about 5.6 per cent of mineral matter, or ash, which is equal to about 112 pounds per acre, while the leaves contain about 2.2 per cent of ash, yielding for the 6,000 pounds about 132 pounds of mineral matter per acre. Crowns and leaves together give a total average yield of 244 pounds of mineral matter per acre. This mineral matter consists for the most part of potash, soda, lime, magnesia, chlorin, sulphuric acid, silica, and phosphoric acid, which are mainly necessary plant foods, so that the value of this by-product as a fertilizer should not be overlooked.

If the leaves and crowns are to be fed to stock, they may be utilized in the fresh state, dried, or siloed. The best method of disposing of this by-product must depend upon local conditions and upon the object sought; that is, whether it is advisable to get the most out of this material from the feeding standpoint or to get it into the form of a fertilizer as soon as possible.

Many beet growers turn their sheep or other stock into the beet fields after the roots have been hauled to the factory. This is the most wasteful method of feeding beet tops, since much of the material is trampled upon and the stock will not eat it. One of the most satisfactory methods of feeding beet leaves and tops is to dry them. This requires extra labor, and if they are artificially dried special machinery is required, which means additional cost. Tops when fresh contain from 85 to 90 per cent of water and when dried from 10 to 12 per cent; that is, in drying there is a loss of about 75 per cent of the original weight of the material, so that the average yield of dried material per acre is about 1 ton, which is considered equal in feeding value to the same quantity of first-class hay. A very small part of this by-product is treated in this manner in this country at present. The cash value of the material as a stock food depends upon the demand and therefore varies with the section and the season.

In some localities, especially in dairy sections, beet tops are siloed with other material for winter and early spring feeding. These silos are filled with alternate layers of beet leaves and some dry material, like straw, which will take up the excess moisture from the leaves. The layers of leaves are, or should be, sprinkled with salt, using about 6 to 8 pounds per ton of leaves. This mixture, if properly siloed, will keep for several years and is considered very satisfactory by dairymen.

Estimating the value of beet tops as $6 per acre, which is at the rate of $1.50 per ton for the fresh material or $6 per ton for it when dried, the total value of this by-product in the United States exceeds $2,000,000. It is evident, therefore, that beet tops have not received the attention due them, either as a fertilizer or as a stock food.

PULP.

The material that remains after the beets have been sliced and the sugar has been extracted is known as pulp. Fresh pulp constitutes about 80 per cent of the weight of the beets. In the process of extraction the beets lose nearly all their sugar, usually only a fraction of 1 per cent being left in the residue or pulp. They also lose a large part of the salts taken up in the process of growth, so that the residue after extraction consists of about 90 per cent water, from 1.5 to 3.5 per cent cellulose, a fraction of 1 per cent each of albuminoids and ash, and about 0.5 to 3.33 per cent extractive substances.

The crop of beets harvested in the United States in 1907 amounted to 3,767,871 tons, which yielded more than 2½ million tons of pulp. This material is disposed of in various ways by the different sugar companies. In some instances it is furnished the beet grower gratis, while in other cases it is sold at a nominal price, from 12½ cents to $1 per ton. At an average price of 50 cents per ton this by-product would represent a return to the sugar companies of more than 1¼ million dollars. Its real value as a stock food has been estimated at from two to three times that amount, depending upon the kind of stock to which it is fed and the object sought; that is, increase in weight, energy, milk flow, butter production, etc.

Efforts have been made to utilize beet pulp in the manufacture of paper and also as a fertilizer. It seems to have a percentage of fiber too low to make it satisfactory in the manufacture of paper. As a fertilizer, it is useful in adding a certain amount of humus to the soil, thereby improving its physical condition. It contains also a small proportion of ash, a fraction of 1 per cent of the wet pulp, which amounts to considerable in the aggregate. Up to the present time its greatest use has been as a stock food. For this purpose it is fed either wet or dried. To be fed in the wet condition, it may be used as soon as it comes from the factory, or it may be left for some time in the factory silo or pit, or the stockman using it may haul it to his farm or ranch and pile it in some convenient place for feeding purposes. The layer of the pulp on the surface of the pile—that is, the part exposed to the air—undergoes certain fermentation changes and should be discarded; for this reason the pulp should be kept in piles as large as practicable, since the larger the diameter of the pile—that is, the greater the bulk of material—the smaller the proportionate loss from surface fermentation. To be fed in the dried condition, it may be dried by itself or it may be mixed with molasses or other edible material before drying. But whether it is to be fed in the wet or in the dried condition it should be mixed with other material before feeding

It is customary in this country and in Europe to feed the pulp mixed with a given amount of grain or oil cake, together with a quantity of chopped hay, straw, dried beet leaves, or material of a similar nature, the proportion of pulp to other material depending upon the object sought. In some instances the grain or oil cake is omitted and only the pulp and roughage fed. According to good authority, the daily ration should amount to only about 6 to 10 per cent of the weight of the animal, so that an animal weighing 1,000 pounds would receive from 60 to 100 pounds of pulp, to which should be added roughage to the extent of 10 to 15 per cent of the weight of the pulp and when desired from 2 to 5 pounds of oil cake or grain per 100 pounds of pulp and roughage.

The dried pulp, according to various analyses, consists of from 8 to 12 per cent of water, 4 to 8 per cent of ash, 7 to 8 per cent of raw protein, 18 to 20 per cent of crude fiber, and from 50 to 60 per cent of nitrogen-free extract. In drying the pulp it is first passed through a press which removes from 10 to 15 per cent of the water, and the remaining wet pulp is then transferred to kilns, where the moisture is reduced to from 8 to 12 per cent, a process which requires from thirty to forty minutes. Other methods may be used in drying the pulp, but whatever the method the purpose is to remove a large part of the water without burning or otherwise changing the composition of the solid matter. In the dried condition the pulp will keep almost indefinitely if stored in a dry place, and it is easily transported. It commands a selling price varying from $12 to $25 per ton, depending upon locality and condition. Good results seem to have been obtained by feeding a mixture of dried pulp (with or without molasses), chopped hay, and oil cake or grain. The total quantity fed must depend, as in the case of the tops, upon the kind of stock and the object sought. While the use of pulp as a stock food has increased rapidly during the last few years, there are still some localities where its value has not yet been recognized.

WASTE MOLASSES.

Waste molasses is the by-product that remains after the crystallizable sugar has been separated from the concentrated beet juice, or molasses. This by-product contains nearly 50 per cent of sugar which cannot be separated from the non-sugars by the ordinary methods, owing to the presence of various salts that have been taken up by the beet from the soil in the process of growth. These salts being soluble are extracted from the beet with the sugar and remain in the molasses. In addition to the sugar and salts in the molasses, there are some organic substances which, with the salts, may be classed as non-sugars. As a rule the larger the proportion of non-sugars present the smaller the quantity of sugar that can be separated, a fact which shows the importance of the purity coefficient. The purity coefficient is the number which shows the relation of the sugar in the juice to the total solids in the juice and is determined by dividing the weight of the sugar in a given quantity of juice by the weight of the total solids (combined weight of sugar and non-sugar) in the same quantity of juice.

In addition to the effect of these salts upon the separation of the sugar, they with the organic matter give to the molasses a disagreeable flavor which prevents it from being used for table purposes. The presence of a large proportion of non-sugars, especially of mineral salt, makes the waste molasses a valuable fertilizer, but it could not be used economically for this purpose owing to the great loss of sugar that would result. However, the non-sugars do not prevent the molasses from being used as a stock food provided too large a quantity is not fed at one time or in one day. Feeding molasses to stock has been practiced in Europe for nearly one hundred years, and yet large quantities of so-called refuse molasses have been wasted in this country because stockmen who might have utilized it did not realize its value. In those sections where it is used as a stock food it is fed to cattle, horses, hogs, sheep, and poultry. It may be dried with beet pulp, alfalfa, or other material for feeding purposes, or it may be used by simply diluting it with about twice its volume of water, in which condition it is fed by itself, or it is sprinkled upon dry hay or other dry fodder. The quantity of molasses used per day depends upon the kind of stock to which it is fed and varies from one-half pound to 6 pounds per thousand weight of the animal. In beginning the use of molasses as a part of the daily ration, it is advisable to start with about one-fourth of the desired quantity and gradually increase the amount from day to day until the full ration is fed. The greatest direct value of the molasses as a stock food is in the sugar, but the non-sugars undoubtedly aid and stimulate digestion and are therefore of great value indirectly if not fed in too large quantities.

Another important use for the waste molasses is in the manufacture of alcohol, including that for denaturing purposes. One gallon of beet molasses, containing about 50 per cent of sugar, weighs approximately 12 pounds and will yield about 3 pints of 95 per cent alcohol; therefore a 50-gallon barrel of waste molasses will produce about 19 gallons of 95 per cent alcohol. Besides alcohol, the distilleries produce as a by-product fusel oil, and the remaining slop or refuse is of great value. Fusel oil finds commercial value in the manufacture of lacquers. Waste molasses is also utilized to some extent in the manufacture of vinegar of a very satisfactory quality.

Certain medicinal preparations have been separated from this slop, such as betaine. The slop or refuse of a distillery contains the salts and organic matter that were present in the molasses. From the concentration of this slop, potash salts are obtained and nitrogen compounds are prepared in Germany and other foreign countries that are used as fertilizers. In this country this waste product known as slop is usually dried and ground up with fish scraps or other material and placed on the market as a commercial fertilizer. When these methods of disposing of the waste molasses are practiced, approximately all the material extracted from the beet is utilized.

Formerly waste molasses was used in Europe in the manufacture of soap, three grades of which were produced, namely, hard, medium, and soft. Efforts are being made by the Office of Public Roads to determine the practicability of utilizing waste molasses in combination with other material in constructing blocks for street-paving purposes. Whether or not these blocks will be sufficiently durable for practical purposes can be determined only by a prolonged test, which is now under way.

When the value of denatured alcohol is better understood it will undoubtedly come into more general use, and it is probable that waste molasses will form an important source of this product. In some countries a portion of the waste molasses is utilized in the manufacture of briquets by mixing coal dust with molasses, pressing, and drying. It is probable that other uses of a more or less important nature will be found for this by-product from time to time, but even with our present knowledge of the value of this important material not one pound of residuary molasses should be allowed to go to waste.

LIME CAKE.

As already stated, there are certain non-sugars in the beet juice that prevent immediate crystallization of the sugar. In order to remove some of these substances the juice is treated with milk of lime. The amount of lime used in the preparation of the milk of lime is generally about 2 to 6 per cent of the weight of the beets sliced; that is, a factory slicing 500 tons of beets a day will require from 10 to 30 tons of lime daily. The amount needed, therefore, for a 100-day run would average about 2,000 tons, making a total for all the factories in the country of nearly 200,000 tons. After the lime has combined with certain substances in the beet juice, the liquid containing the sugar is pressed through filter cloths and the lime cake remains behind. Comparatively little use has been made of this by-product in this country, while in Europe it is in general use as a fertilizer. So far as we have tested lime cake as a fertilizer it has given satisfactory results in nearly all cases. It is to be especially recommended in the case of acid soils and hard soils that need some material to make them more friable. It is certainly an enormous waste of valuable material to wash the lime cake into the sewers and gullies, as is done in the great majority of American factories at the present time. The difficulty in handling this material and spreading it uniformly over the land is a serious hindrance to its use as a fertilizer. The cost of transportation is also an important consideration in this connection. In a few irrigated sections the lime cake is washed out over the fields with the waste water, under which condition it is spread more or less uniformly and appears to be very beneficial to alfalfa and other field crops. If it could be passed through some process or mixed with some material that would render its handling easier, it would undoubtedly come into more general use as a fertilizer.

Numerous efforts have been made to utilize the lime cake in the manufacture of cement in this country, but, so far as can be ascertained, the tests made have not yet been entirely satisfactory. In Germany this industry has reached commercial importance. That lime cake will eventually be used for some such purpose there can be no doubt. A small amount of waste lime from beet sugar factories is now being used in the manufacture of a wall board, the principal ingredients of which are coal tar and waste lime. It has been used in the construction of pavements, roofing, etc., by drying, pulverizing, and mixing with asphaltum.

As the beet-seed industry develops in this country, several additional by-products of the sugar beet will deserve attention, namely, the seed beets after they have gone to seed, seed stalks, and refuse seed. The seed beets increase in size during the second year, often attaining a weight from two to four times as great as the beets had at the end of the first season. The sugar content also deserves considerable attention, often varying from 10 to 14 per cent after the seed has been harvested at the end of the second season. These roots, therefore, represent considerable material per acre, usually from 8 to 10 tons of roots, which, owing to their woody, fibrous nature, are not readily workable in the sugar mill. If passed through a chopper they may be utilized as a stock food, or, considering the large quantity of sugar present, they may be employed in the manufacture of alcohol. At the present time less than 300 acres of beet seed are grown in this country, so that the loss from the non-utilization of these roots is less than in the case of any of the by-products previously mentioned. As the beet-seed industry develops, however, this by-product will become of great importance. Future possibilities along this line may be realized when we remember that the present needs of this industry call for the total seed production of 5,000 acres and that the industry may be increased fivefold. When this stage of development is reached there will be at least 250,000 tons of seed beets to be utilized in some manner each year.

The seed stalks also represent a large amount of waste material. In Europe efforts have been made to utilize the seed stalks by chopping them up and mixing them with some of the waste molasses for stock food, but owing to their dry, fibrous condition they do not seem to be satisfactory for this purpose. Whether or not any practical use can be found for them remains to be determined.

It sometimes happens that the seed, because of its age or for some other reason, is not satisfactory for planting. It is then best utilized by transforming it into a meal by grinding, when it may be used as a stock food, thereby preventing it from becoming a total loss. Ground beet seed is composed of from 10 to 12 per cent water, 13 to 17 per cent protein, 4 to 8 per cent fat, 32 to 45 per cent nitrogen-free extractive, 13 to 18 per cent crude fiber, and 5 to 13 per cent ash. The ash contains from 20 to 25 per cent potash, 4 to 22 per cent lime, and from 14 to 46 per cent phosphoric acid. It is evident, therefore, that ground beet seed is valuable for cattle feeding and makes an important addition to the stable manure. In this connection it should be added that under ordinary conditions beet seed will retain its vitality for several years, so that there is little probability under existing circumstances of being obliged to utilize the seed for other purposes than planting.

OTHER WASTE MATERIAL.

In addition to the by-products mentioned, there are several kinds of refuse in sugar factories that should be noted in this connection, namely, waste water, old filter cloth, rubber belting, and gunny sacks.

A 500-ton factory requires about 2½ million gallons of water daily during the time the factory is in operation. This is used in washing the beets, extracting the sugar from the cossettes, in the production of steam, etc. A greater part, however, of the water is used in washing the beets and is allowed to flow off as waste material after it has served its purpose in the factory. In only a few cases is this waste water utilized, but when practicable it has been found very useful for washing alkali out of the soil, for irrigation purposes, or for washing the pulp and lime cake away from the factory.

The old filter cloth is sometimes sold to nurserymen, who use it for wrapping material, or to tomato growers, who use it to protect their plants from late frosts.

Rubber belting when discarded finds ready sale for brake-block lining and for rubber recovery. The large quantities of cloth and belting used in sugar factories make these items of considerable importance as waste material.

A sugar factory utilizing the raw material from 5,000 acres will have not less than a thousand gunny sacks each year that were used in transporting the seed to the factory. If the seed were grown in this country the sacks could be used over and over, but it would not be economy to ship them back to Europe to be refilled. For this reason the factories have large numbers of these sacks on hand, many of which are utilized about the mills in various ways, while others are disposed of to farmers and other buyers at a low price, but amounting to a considerable sum in the aggregate. These sacks are useful in handling potatoes and other vegetables, in covering seed beets and other roots that are to be kept through the winter for seed production, and in many other ways about the farm and garden.

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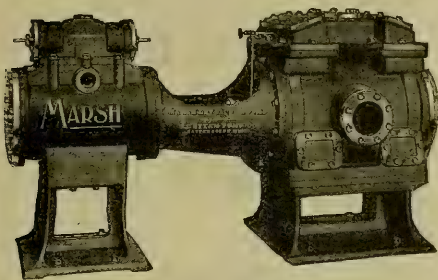

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